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In This Issue . . .

Banking reformers of the early 20th century often attributed financial crises to the failure of the nation's currency and credit supplies to increase sufficiently to meet seasonal and extraordinary demands. The Federal Reserve System was established to accommodate these demands, and from the System's founding until the stock market crash in 1929, no crises or banking panics occurred.

In the first article in this *Review*, "Seasonal Accommodation and the Financial Crises of the Great Depression: Did the Fed 'Furnish an Elastic Currency?'" David C. Wheelock investigates a recent claim that the reappearance of financial crises during the Depression was caused by a reduction in the Fed's accommodation of seasonal currency and credit demands. His review of Fed procedures and statistical evidence about the Fed's use of its policy tools and about market outcomes suggests no change in seasonal policy. The Federal Reserve may rightly be criticized for failing to offset dramatic nonseasonal increases in currency and reserve demands during the Depression, he says, but it appears unlikely that the financial crises of the Depression were caused by a change in the System's seasonal policies.

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Policymakers are currently debating the importance of protecting high-technology industries through trade and industrial policies. Some, such as Laura D'Andrea Tyson, the current chair of the Council of Economic Advisers, argue that protective policies are necessary because our trading partners are protecting their high-technology industries. Others argue that the market system will provide all the assistance high-technology industries need. Implicit in these arguments is the assumption that high-technology industries are somehow special.

In the second article in this *Review*, "Is the United States Losing Its Dominance in High-Technology Industries?" Alison Butler provides a careful analysis of U.S. high-technology industries. She discusses why high-technology industries are considered valuable to an economy and examines several performance indicators for high-technology industries in the United States. When possible, Butler compares U.S. indicators with similar indicators in Japan and Germany. She shows that high-technology industries have a significant positive effect on economic growth and that continued U.S. participation in these industries will help maintain high-wage/high-skill jobs and continued economic growth in the United States.

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In the hope of encouraging empirical work in monetary economics—particularly work to determine the importance of different methods of monetary aggregation—Daniel L. Thornton and Piyu Yue, in the third article in this *Review*, discuss monetary aggregation and present an extended data series of Divisia monetary aggregates. Data from January 1959 to the present are used in this article.

In "An Extended Series of Divisia Monetary Aggregates," Thornton and Yue briefly analyze the behavior of five Divisia aggregates—M1A, M1, M2, M3 and L. Their analysis suggests that the method of aggregation is not likely to be empirically important for narrow monetary aggregates like M1A and M1 and that beyond some point, successively broader Divisia monetary aggregates are likely to behave similarly in applied work.

Data on the simple-sum and Divisia monetary aggregates presented in this article are available from the St. Louis Fed. For details, please see p. 52.

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David C. Wheelock

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Seasonal Accommodation and the Financial Crises of the Great Depression: Did the Fed "Furnish an Elastic Currency?"

It was not by accident that most of the money panics in this country occurred in the fall of the year; it was in the fall that the usual seasonal strain, added to an unusual credit and currency stringency, became the last straw that broke the camel's back.

—W. Randolph Burgess (1936), p. 206.

BEGINNING WITH THE stock market crash in October 1929, the United States suffered a series of financial crises that mark the Great Depression. In each crisis, the number of bank failures and the declines in bank reserves, the money stock and economic activity were greater than in the preceding episodes. Many researchers investigating the causes of financial crises during the Great Depression have blamed the Federal Reserve, for either pursuing policies that led to crises or for failing to respond to them appropriately.[1]

This article investigates a recent claim by Miron (1986) that the reappearance of financial crises in 1929 was caused by a reduction in the Fed's accommodation of seasonal currency and credit demands.[2] The following three types of evidence are examined: the Fed's procedures for supplying currency and bank reserves across seasons, the stability of the seasonal behavior of the Fed's policy tools and the seasonal behavior of market interest rates. The Fed's accommodation of seasonal demands was passive, suggesting that a deliberate change in seasonal policy

[1]See, for example, Friedman and Schwartz (1963), Chandler (1971), Miron (1986) and Wicker (1966). The continuing debate about the role of Federal Reserve policy during the Great Depression generally is reviewed by Wheelock (1992).

[2]Miron (1986, p. 136) argues that "the Fed accommodated the seasonal demands in financial markets to a lesser extent during the 1929-33 period than it had previously. This means that the frequency of panics *should* have increased, as it did" (Miron's emphasis).

was unlikely. Statistical analysis of the seasonal patterns of the Fed's policy tools and of market outcomes suggests further that no change in seasonal policy occurred. The Federal Reserve may rightly be criticized for failing to offset dramatic nonseasonal increases in currency and reserve demand during the Depression. It appears unlikely, however, that the financial crises were caused by a change in the System's seasonal policies.

The first sections of this article discuss the objectives of the Fed's founders, particularly with regard to seasonal accommodation, and describe how Fed officials implemented those objectives. A review of how the Fed's presence affected the seasonal pattern of interest rates and the frequency of financial crises follows. Finally the article examines whether a change in seasonal policy was a likely cause of the reappearance of crises in 1929, first focusing on the Fed's procedures and then on statistical evidence pertaining to the seasonal patterns of Fed tools and market outcomes.

FINANCIAL CRISES AND THE FOUNDING OF THE FEDERAL RESERVE SYSTEM

The Federal Reserve was founded to correct banking system flaws that reformers believed contributed to financial crises. The National Banking era, which began with the National Bank Act of 1863 and ended with the opening of the Federal Reserve Banks in November 1914, was marked by recurrent crises. Often a crisis was touched off by a sudden international gold outflow or the failure of a major financial institution. Occasionally such an event triggered a general run by bank depositors seeking to convert deposits into currency. In extreme cases, banks were forced to suspend currency payments and call loans to protect their reserves. National Banking era crises were generally characterized by high interest rates, many bank failures, and a slowing of economic activity.[3]

Studies of financial crises during the National Banking era noted that crises generally occurred at times of the year when demands for currency and credit reached seasonal peaks. In his study for the National Monetary Commission, Kemmerer (1910, pp. 222–23) wrote the following:

> It has been found that the two periods of the year in which the money market is most likely to be strained are the periods of the 'spring revival,' about March, April, and early May, and that of the crop-moving demand in the fall; and that the two periods of easiest money market are the 'readjustment' period, extending from about the middle of January to nearly the 1st of March, and the period of the summer depression, extending through the three summer months. Of the eight panics [of the era], four occurred in the fall or early winter ... and these four included two of the three really severe panics of the period (i.e., those of 1873 and 1907); three occurred in May ... and one, ... probably the least important, ... extended from March until well along in November.
>
> The evidence accordingly points to a tendency for panics to occur during the seasons normally characterized by stringent money markets. This does not mean that the seasonal stringencies are the causes of the panics; it does mean that the months in which they occur are the weakest links in the seasonal chain, and that in periods of extraordinary tension the chain breaks at these links.

Reformers attributed the crises of the National Banking era to inelasticity in the nation's currency supply. National bank notes, U.S. government currency issued during the Civil War (Greenbacks), silver certificates and specie (gold coin) were the principal currency forms during the National Banking era. Federally chartered (national) banks were permitted to issue notes valued at up to 90% (later 100%) of the face value of U.S. government bonds they pledged with the Comptroller of the Currency. The supply of national bank notes was thus tied to the volume of government bonds outstanding and the profits national banks could earn issuing notes using these bonds as security. The sup-

[3]There is no generally accepted definition of financial crisis. Rather than defining the term, researchers often list characteristics of financial crises (for example, Bordo, 1986). According to Schwartz (1986, p. 11), "A financial crisis is fueled by fears that means of payment will be unobtainable at any price and, in a fractional-reserve banking system, leads to a scramble for high-powered money. It is precipitated by actions of the public that suddenly squeeze the reserves of the banking system. In a futile attempt to restore reserves, the banks may call loans, refuse to roll over existing loans, or resort to selling assets." Schwartz distinguishes between real crises, in which financial distress leads to a sudden decline in the money supply, and pseudo-crises, which do not have money supply consequences. Kindleberger (1989), however, argues against such a distinction. This article uses the terms *crisis* and *panic* interchangeably. See Sprague (1910) for an overview of financial crises during the National Banking era and Dwyer and Gilbert (1989) for a study of the effects of banking panics in this era.

plies of Greenbacks and silver certificates were fixed, as was the supply of specie for short periods. The currency supply was thus relatively inflexible and could not be increased sufficiently to accommodate a sudden large-scale attempt by depositors to convert funds into cash. A means of supplying large amounts of currency rapidly was key to most banking reform proposals.[4] Reformers proposed a system in which the supplies of currency and credit fluctuated with the needs of trade. The theoretical justification for such a system became known as the Real Bills Doctrine, and that doctrine was implemented with passage of the Federal Reserve Act.[5]

SEASONAL ACCOMMODATION BY THE FEDERAL RESERVE

The title of the Federal Reserve Act states that one purpose of the Federal Reserve System is "to furnish an elastic currency."[6] Member commercial banks were required to hold reserve deposits with the Federal Reserve Banks instead of holding specie or deposits with Central Reserve City and Reserve City banks, as they had under the National Banking System. The Federal Reserve Act also provided for a new currency form—the Federal Reserve note. W. Randolph Burgess (1936, p. 150), a long-time official at the Federal Reserve Bank of New York, argued the following:

> The fundamental change which the Federal Reserve System has made ... is to shift much of the burden of meeting the fluctuations in the demand for credit from the reserves of the member banks in New York City to the twelve Reserve Banks, which through the strength of their holding of pooled reserves and through their power of note issue and deposit expansion can provide almost any extra funds required.

A member commercial bank could accommodate an increase in loan demand or currency withdrawals by rediscounting eligible commercial paper with its Federal Reserve Bank. The Federal Reserve Bank would provide the commercial bank with reserves or currency and charge its discount rate.[7]

The provision of currency and reserves by the Federal Reserve Banks was intended to be largely automatic and self-regulating. Proponents of the Real Bills Doctrine believed that the quantities of currency and reserves provided by the Fed would be sufficient but not inflationary if supplied on the basis of short-term commercial loans.[8] The Federal Reserve Banks were authorized to rediscount commercial, agricultural and industrial paper, bankers acceptances used to finance foreign trade, and U.S. government securities with maturities of up to three months. Consistent with the Real Bills Doctrine, Federal Reserve Banks were not authorized to rediscount loans used to support purely financial activity, such as stock market call loans, because they were believed to be inflationary or speculative.[9] The Federal Reserve Banks set discount rates, subject to approval by the Federal Reserve Board, and generally supplied currency and reserves elastically through the discount window. The Federal Reserve Banks also supplied reserves by purchasing bankers acceptances outright. They set buying rates and purchased all acceptances that met minimum quality standards, thus supplying reserves freely at the buying rates.

Besides setting discount and acceptance buying rates, the Federal Reserve Banks were permitted to buy and sell U.S. government securities. The Fed's founders did not envision use of this authorization to conduct monetary policy as we

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[4]A variety of currency substitutes were used during the banking panics of the National Banking era. Loan certificates issued by clearinghouses have been the most studied (see Dewald [1972], Timberlake [1984], Gorton [1985], and Dwyer and Gilbert [1989]). The Aldrich-Vreeland Act of 1908 permitted bank associations to issue "emergency currency" during panics, which in essence made legal the earlier practice of issuing clearinghouse certificates.

[5]See Friedman and Schwartz (1963, pp. 168-73), West (1977) or Timberlake (1978, pp. 186-206) for discussions of the reform movement and analysis of various proposals.

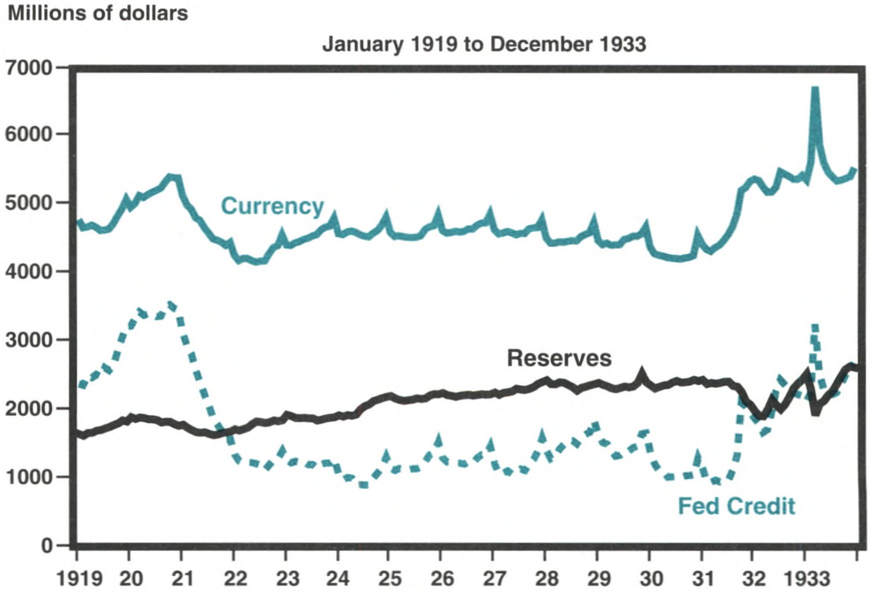
[6]The title of The Federal Reserve Act reads, "An Act to provide for the establishment of Federal Reserve Banks, to furnish an elastic currency, to afford means of rediscounting commercial paper, to establish a more effective supervision of banking in the United States, and for other purposes."

[7]This action was originally known as rediscounting because commercial bank loans were often made on a discount basis; hence when they were endorsed by a commercial bank and sent to a Federal Reserve Bank, they were rediscounted by the Fed.

[8]Because the Fed was required to maintain gold reserves equal to a fraction of its deposit and note liabilities, the gold standard ultimately constrained the growth of reserves and currency. In practice, however, the Fed maintained excess gold reserves, so the reserve requirement had little effect on its operations before 1931.

[9]Eligibility requirements were somewhat broadened in 1916 to include acceptances arising from domestic trade, and Federal Reserve Banks were authorized to lend directly to member banks on their own notes secured by eligible paper. See Board of Governors of the Federal Reserve System (1943, pp. 325-26) for a summary of the types of paper eligible for rediscount and for significant changes in eligibility rules from 1914 to 1933.

Figure 1
The Accommodation of Currency Demand



know it today, however, but rather to provide the Federal Reserve Banks with an additional means of generating revenue. The use of monetary policy to influence economic activity and the price level and for other general purposes evolved slowly, and open market operations were not important until the mid-1920s.[10]

In accommodating the demands of commercial banks, Federal Reserve credit tended to increase in the spring and autumn months, when commercial loan demand peaked, and again in December, with increased holiday demand for currency. After the holidays, currency returned to banks and credit demand declined as it did during the summer. Federal Reserve credit tended to decline in winter and summer months.

After the Fed's establishment, the behavior of short-term interest rates changed dramatically. Before 1914, rates had a distinct seasonal pattern—high in the autumn and spring and low during the winter and summer. According to Burgess (1936, p. 204):

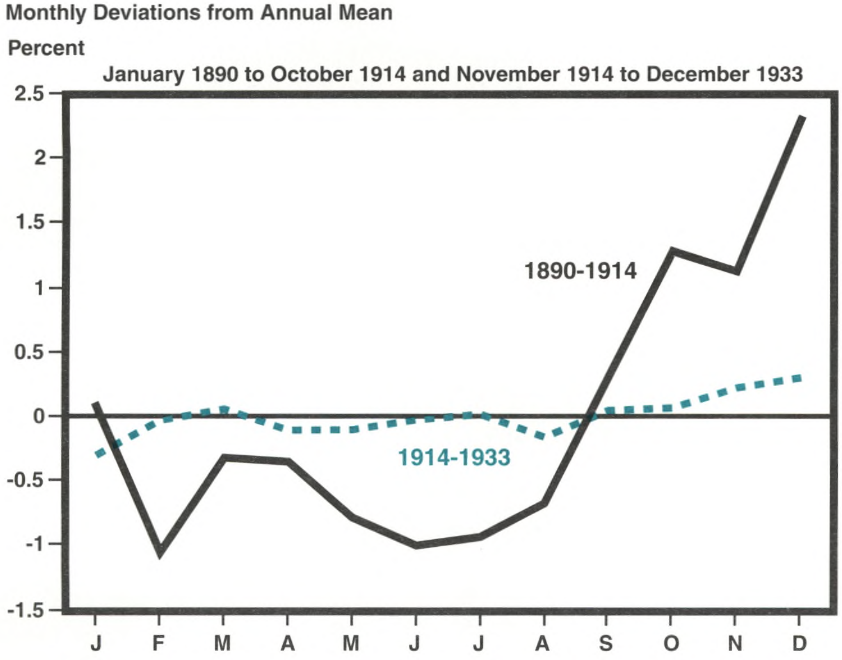
> (M)oney rates fluctuated much more rapidly and widely before the Federal Reserve System was established. . . . In January and February money tended to be easy. In the early spring rates rose, as the demand for funds increased with the planting of crops and spring trade. Towards summer rates fell, but rose again to the year's high point in the autumn with harvesting and autumn trade. They continued generally high throughout the holiday period with its heavy currency requirements. . . . Since the establishment of the Reserve System, such seasonal swings of interest rates have been almost though not quite eliminated.

Burgess (p. 206) goes on to write, "The explanation of the change which has taken place is found largely in the credit elasticity provided by the Reserve System." Other writers have recognized the Fed's influence on the pattern of rates. Friedman and Schwartz (1963, pp. 292–93), for example, conclude the following:

> The Federal Reserve 'sterilized,' as it were, seasonal withdrawals and returns of currency and thereby kept deposits of member banks at

[10]See Chandler (1958), Friedman and Schwartz (1963), Wicker (1966) and Wheelock (1991, 1992) for discussion of the evolution of monetary policy and the Fed's objectives during the 1920s and early 1930s.

Figure 2
The Seasonal Pattern of the Call Loan Rate



the Reserve Banks largely, though not entirely, free of seasonal movements. The effect was to change the pre-1914 seasonal patterns notably. The seasonal pattern in currency outside the Treasury was widened, the seasonal pattern in call money rates narrowed. The System was almost entirely successful in the stated objective of eliminating seasonal strain.

The contribution the Federal Reserve made to accommodating seasonal (and nonseasonal) currency demands is illustrated in figure 1.[11] Federal Reserve credit and currency in circulation tended to move together. Federal Reserve credit is a source of bank reserves, so by extending Fed credit when currency was withdrawn from banks, the Fed reduced fluctuations in member bank reserves.[12]

The seasonal pattern of interest rates changed after the Fed opened in November 1914. Figure 2 shows the estimated seasonal patterns of the call loan renewal interest rate between January 1890 and October 1914 and between November 1914 and December 1933.[13] In the earlier period the interest rate fluctuated much more widely during the year than it did after the Fed's founding. Many studies, using a variety of statistical techniques, confirm the apparent decrease in seasonal amplitude illustrated here.[14] Scholars debate whether the Federal Reserve was respon-

[11]The data plotted in figure 1 are monthly averages of daily figures. The source for these data is the Board of Governors of the Federal Reserve System (1943, pp. 369-71).

[12]As discussed later, this study begins its analysis in 1919 because there is controversy about the Fed's effects in its early years and because of the disruptions caused by the Fed's contribution to financing World War I.

[13]The plotted seasonal patterns are simply the monthly averages of the rate less the annual mean, after subtracting a time trend. The patterns are calculated from a linear regression of the interest rate on monthly dummy variables and a time trend, which included an AR(2) error process and was estimated using maximum likelihood. It might be argued that it would be more appropriate to examine the behavior of real interest rates because the underlying sources of seasonal credit and currency demands are real phenomena. Miron (1986) argues, however, that nominal rates should reflect the extent of the Fed's seasonal accommodation, and most studies have focused exclusively on the behavior of nominal rates.

[14]See Shiller (1980), Clark (1986), Miron (1986), Mankiw, Miron, and Weil (1987), Fishe and Wohar (1990), Canova (1991), Fishe (1991), and Holland and Toma (1991).

sible for this change, particularly before the end of World War I.[15] Researchers generally agree, however, that the evidence for a significant Fed role after World War I is strong. Clearly the Fed intended to accommodate seasonal currency and credit demands, as the following statement of Reserve Bank policy in the first *Annual Report of the Federal Reserve Board* (1914, p. 17) indicates: "The more complete adaptation of the credit mechanism and facilities of the country to the needs of industry, commerce, and agriculture—with all their seasonal fluctuations and contingencies—should be the constant aim of a Reserve Bank's management."[16]

SEASONAL ACCOMMODATION AND FINANCIAL CRISES

The elasticity of currency and reserves supplied by the Fed and the near elimination of seasonal fluctuations in interest rates successfully eliminated financial crises — or so it appeared until 1929. From the Fed's founding until the stock market crash, no crises or banking panics occurred despite a significant recession in 1921, minor recessions in 1924 and 1927, and 5,700 bank failures during the 1920s.

In the following passage Burgess (1927, p. 122) noted that Fed operations apparently eliminated financial panics:

> In the old days there were rigid and not far distant limits to the reserves available; now the mechanism of the Reserve System provides for a much larger possible expansion. It gives much greater elasticity . . . . This elasticity results in much more stability of rates and practically eliminates the fear of money panic . . . .

Burgess argued further that, "The presence of the Reserve System gives greater elasticity to the supply of funds and stability to the money market and removes the fear of money panics" (p. 125).[17] Miron (1986, p. 136) also concludes "that the Fed successfully eliminated financial panics from 1915 to 1928." Based on historical experience, he calculates that the probability of there being no financial crises in a 14-year period (for example, from 1915 to 1928) is .005.

Like Miron (1986), other researchers have concluded that the crises of the Great Depression resulted from a distinct change in Federal Reserve policy. Following Friedman and Schwartz (1963), Miron attributes the change in policy to the death of Benjamin Strong, governor of the Federal Reserve Bank of New York and the Fed's leading policymaker, in October 1928. Other researchers, such as Trescott (1982) and Hamilton (1987), also conclude that monetary policy changed significantly with, or just before, the onset of the Depression.[18] The remainder of this article examines whether there was a change in Federal Reserve accommodation of seasonal currency and credit demands that could explain the reappearance of financial crises beginning in October 1929.

FEDERAL RESERVE METHODS OF SEASONAL ACCOMMODATION

How did the Federal Reserve accommodate seasonal currency and credit demands during the Great Depression? A review of the Fed's methods indicates that the Fed was largely passive in this accommodation, suggesting that any apparent change in the seasonal pattern of Federal Reserve credit was more likely due to changes in demand than to a deliberate policy decision.

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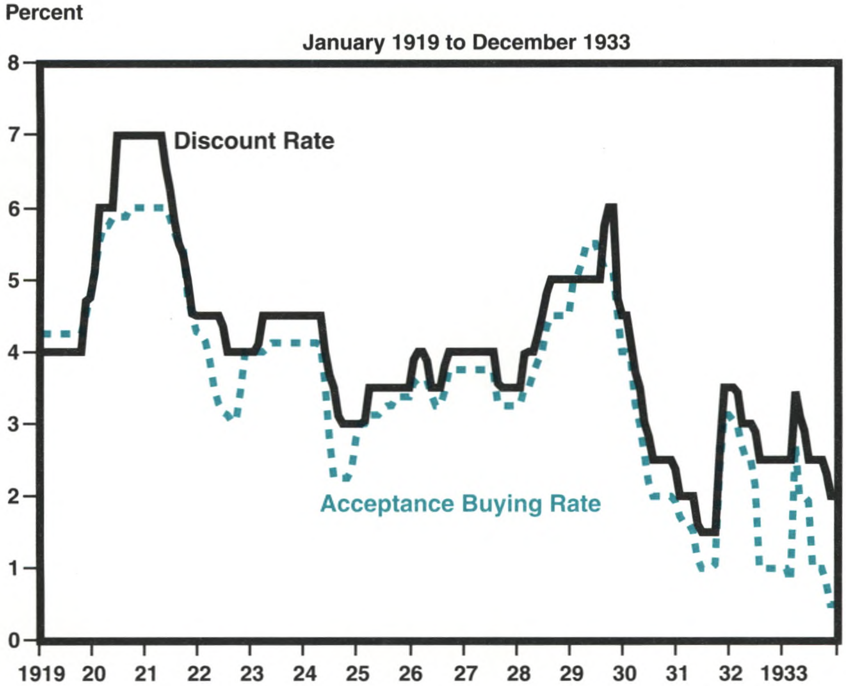
[15]Miron (1986) and Mankiw, Miron and Weil (1987) argue strongly that Federal Reserve operations caused the seasonal fluctuations in short-term nominal interest rates to decline after 1914. Clark (1986), however, contends that a lowering of reserve requirements, which occurred simultaneously with the Fed's opening, and gold inflows accompanying the start of World War I are more likely causes of the reduced seasonal pattern of interest rates in the United States between 1914 and 1917. Fishe (1991) also reaches this conclusion, finding little seasonal behavior before 1917 in any variable under the Fed's control. Holland and Toma (1991) argue, however, that the Fed's presence as lender of last resort may have made banks more willing to lend in seasons during which credit demand was high and thus might have caused a reduction in interest rate seasonality even though there was little seasonal behavior in Federal Reserve credit until the 1920s.

[16]The Federal Reserve continues to accommodate seasonal variation in money and credit demands. The Fed uses open market operations to remove seasonal changes in the money stock, and its seasonal borrowing program permits special discount window access to banks that experience large seasonal fluctuations in loan demand. See Clark (1992) for a discussion of this program.

[17]In the second edition of Burgess' book (1936, p. 156), published after the financial crises of the Great Depression, both of these sections were changed. The latter was modified to read "The presence of the Reserve System gives greater elasticity to the supply of funds — and the control of that elasticity is the central problem of Federal Reserve policy."

[18]Specifically, Trescott dates the change in policy to early 1930, when the Fed's open market committee was reorganized; Hamilton dates the policy change to December 1927, when the Fed adopted a restrictive policy to combat stock market speculation. Other studies, however, have concluded that there was no fundamental change in Federal Reserve policy at this time. This debate is examined in Wheelock (1991, 1992).

Figure 3
Federal Reserve Discount and Acceptance Buying Rates



The Fed had the following three main policy tools during the 1920s and early 1930s: the discount rate, the acceptance buying rate and open market operations in U.S. government securities.[19] The Fed was established to provide currency and bank reserves to accommodate the needs of commerce. By specifying eligibility requirements for the paper that could be rediscounted or purchased, the Fed's founders intended to limit policymakers' discretion, as well as to accommodate currency and credit demands without fueling inflation or speculation.

Only in open market operations in government securities did the Fed determine the specific volume of its operations. The Fed was generally passive in supplying currency and bank reserves through the discount window and by purchasing acceptances.[20] The Federal Reserve could of course affect the volume of discount loans and acceptance purchases by altering the discount and acceptance buying rates, but neither rate had a seasonal pattern (see figure 3).[21] Apparently the Fed did not alter its rates to influence seasonal changes in discount-window borrowing or in its acceptance holdings, although it may have altered rates for other reasons. The three panels of figure 4 plot Federal Reserve credit outstanding and its principal components. Each component had a statistically significant seasonal pattern, but changes in the Fed's acceptance portfolio and in discount loans were the principal causes of seasonal variation in total Fed credit outstanding. The only component whose volume the Fed controlled directly—the government security

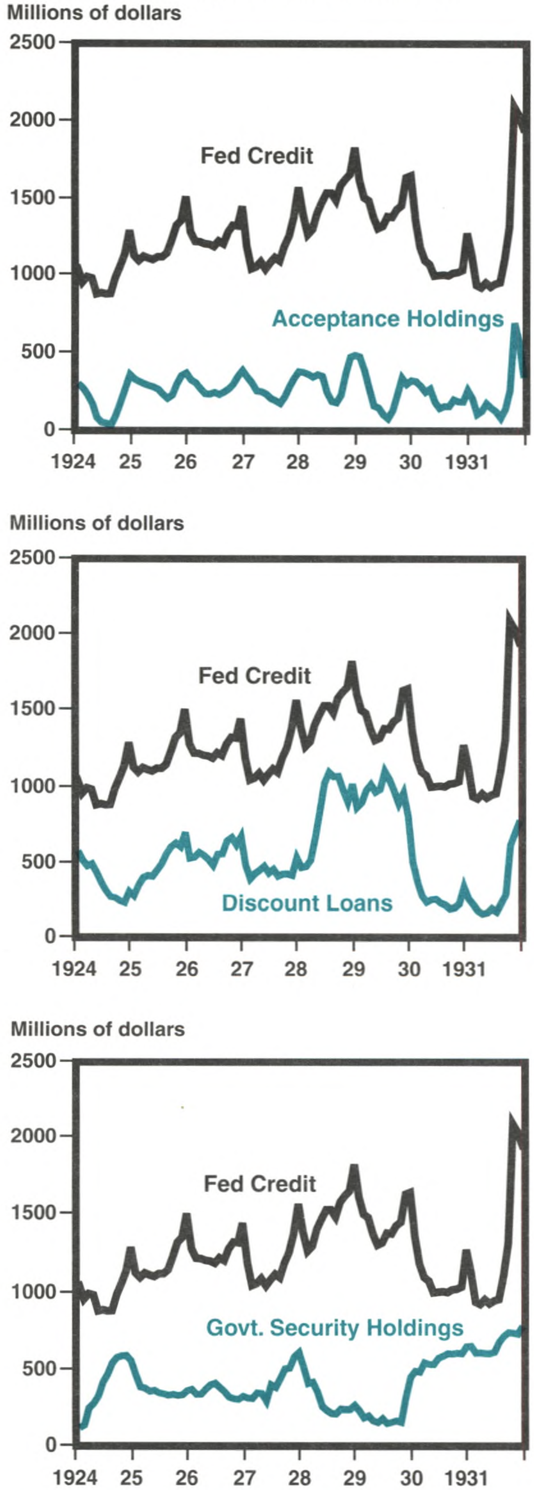
[19]The Fed did not have the power to alter reserve requirements until 1933.

[20]Burgess (1936, p. 42).

[21]I regressed each rate on a time trend and monthly dummy variables, and each regression included an AR(2) error process. Neither rate nor its first difference had a statistically significant seasonal pattern. An F-test of the null hypothesis that the coefficients on the monthly dummies equal zero cannot be rejected for either rate or its first difference. The source of these data is Board of Governors of the Federal Reserve System (1943, pp. 439-45). For months in which a rate changed, I computed a monthly average by weighting the rate by the number of days it was in effect.

Figure 4
Fed Credit Outstanding and Its Principal Components

January 1924 to December 1931



portfolio—had the least seasonal pattern. The absence of seasonal changes in the discount and acceptance buying rates and the minimal contribution of open market operations in government securities to the seasonal pattern of Federal Reserve credit indicate that the Fed's accommodation of seasonal currency and credit demands was largely passive. It seems likely therefore that a shift in demand, rather than a deliberate policy action affecting supply, explains any change in the seasonal behavior of Federal Reserve credit outstanding.[22]

EMPIRICAL EVIDENCE ON THE STABILITY OF SEASONAL PATTERNS

The reappearance of financial crises in 1929 at times of the year when credit and currency demands reached seasonal peaks suggests that the Fed might have reduced its accommodation of seasonal demands. Miron (1986) contends that this was true because he finds that the seasonal fluctuations of Federal Reserve credit were somewhat less pronounced between 1929 and 1933 than they had been between 1922 and 1928.

Miron estimates the seasonal pattern of Federal Reserve credit by calculating the unconditional mean of Fed credit in each month after subtracting a time trend. A convenient way of doing this is to regress the series on monthly dummy variables and a time trend. Miron finds that the range and standard deviation of the estimated dummy variable coefficients are smaller in the 1929–33 period than in the 1922–28 period and infers that Federal Reserve credit had less seasonal variation during the Depression than it had previously.[23] He concludes therefore that the Fed was less accommodative of seasonal demands after 1928 than it was before 1928.

Using Miron's methodology but estimating the pre-Depression seasonal pattern over a somewhat longer period (1919–28), I find that Federal Reserve credit actually had greater seasonal amplitude during the Depression years. Figure 5 plots the seasonal patterns of Federal Reserve

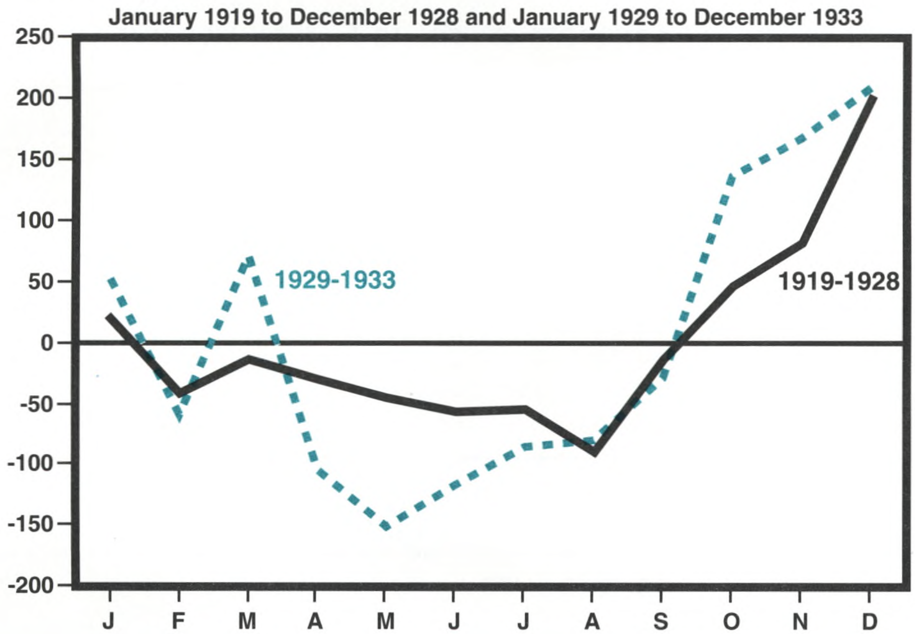
[22]Federal Reserve credit also included a miscellaneous component that was mainly float, which averaged about 4 percent of total Fed credit outstanding. This component was also somewhat seasonal and, like discount loans and acceptances, was influenced more by the level of economic activity than by Fed policy.

[23]Miron does not test whether the changes are statistically significant.

Figure 5
The Seasonal Pattern of Federal Reserve Credit

Monthly Deviations from Annual Mean

Millions of dollars



credit between 1919 and 1928 and between 1929 and 1933.[24] These data do not suggest a decline in Fed accommodation after 1928.

Table 1 presents evidence on the statistical significance of the seasonal patterns of Federal Reserve credit and its chief components—the Fed's acceptance holdings, discount window loans and government security holdings. Continuing with Miron's methodology, I estimate the seasonal patterns of each series and the change (first difference) of each series as the average values for each month after removing any time trend. These averages are simply the estimated coefficients from a regression of each variable on monthly dummy variables and, for the non-differenced data, a time trend.[25] The seasonal pattern is statistically significant if the null hypothesis that the estimated monthly dummy coefficients equal zero can be rejected. Table 1 reports the test statistics for this hypothesis. Between 1919 and 1928, Federal Reserve credit and each component had statistically significant seasonal patterns.[26] Between 1929 and 1933, however, only the Fed's government security portfolio had a statistically significant seasonal pattern. These tests appear to suggest that the Fed was less accommodative of seasonal demands during the Depression. The smaller F-statistic values for Fed accommodation of seasonal demands during the Depression are not, however, necessarily evidence of less seasonality because with fewer observations the seasonal patterns are estimated less precisely. Thus the conclusions drawn from them are less certain.

[24]The figure plots the estimated dummy coefficient for each month less the average of the 12 estimated coefficients. In addition to the dummy variables, the model includes a time trend and an AR(2) error process (which was suggested by standard model selection criterion) and was estimated using maximum likelihood.

[25]Model selection criterion suggested the use of an AR(2) error process in modeling Federal Reserve credit and an AR(3) process for each component. I used AR(1) for the change in Federal Reserve credit and AR(2) for the changes in each component. I also estimated models for the difference in the logs of each variable. The results for these models are identical to those of the first-difference models.

[26]Because researchers who argue that Fed policy changed do not agree on the date of this change, I chose to follow Miron (1986) and break the sample at December 1928. Breaking the sample at December 1927, however, does not qualitatively change the results.

Table 1

Significance of Seasonal Patterns in Federal Reserve Credit and its Components (F-Test Statistics)

	January 1919–December 1928	January 1929–December 1933	January 1929–September 1931
Federal Reserve credit	23.48**	0.99	3.47**
Acceptances	4.10**	1.79	1.90
Discount loans	5.42**	1.04	1.24
Government securities	4.02**	2.02*	2.54*
Change in Federal Reserve credit	25.00**	1.15	4.59**
Change in acceptances	4.26**	1.47	2.29
Change in discount loans	5.70**	0.90	1.55
Change in government securities	3.08**	1.71	2.07

* Statistically significant at the .05 level.
** Statistically significant at the .01 level.

Data source: Board of Governors of the Federal Reserve System (1943), pp. 369-71. The data are monthly averages of daily figures.

Table 2

Stability of Seasonal Patterns in Federal Reserve Credit and its Components, December 1928 Breakpoint (F-Test Statistics)

	January 1919–December 1933	January 1919–September 1931
Federal Reserve credit	1.02	1.55
Acceptances	1.68	2.61**
Discount loans	1.24	1.02
Government securities	0.70	0.79
Change in Federal Reserve credit	1.17	1.53
Change in acceptances	2.04*	2.84**
Change in discount loans	1.33	0.92
Change in government securities	1.13	0.98

* Statistically significant at the .05 level.
** Statistically significant at the .01 level.

Table 3

Stability of Seasonal Patterns in Federal Reserve Credit and its Components (Standard Deviations of Monthly Dummy Coefficients)

	January 1919–December 1928	January 1929–December 1933	January 1929–September 1931
Federal Reserve credit	75.41	116.69	139.02
Acceptances	47.52	65.38	72.74
Discount loans	34.58	47.91	64.39
Government securities	10.88	47.94	41.34
Change in Federal Reserve credit	50.19	90.84	78.63
Change in acceptances	27.79	47.01	48.62
Change in discount loans	22.13	56.16	24.95
Change in government securities	16.04	29.97	33.17

The results of further tests for a change in the Fed's seasonal accommodation are presented in table 2 and table 3. Table 2 summarizes tests to determine whether seasonal patterns of Fed credit and its components before December 1928 were significantly different from seasonal patterns after December 1928. Except for the change in the Fed's acceptance holdings, these tests indicate no change in seasonal patterns.[27]

Table 3 reports the standard deviations of the monthly dummy coefficients for each variable in each period.[28] Miron (1986) concluded that the Fed was less accommodative during the Depression in part because the standard deviation of the seasonal pattern of Fed credit was smaller between 1929 and 1933 than it had been between 1922 and 1928. Although comparing the standard deviations of the seasonal patterns is not a statistically rigorous test, it does provide evidence that the seasonal variability of each series increased or decreased over time. The standard deviation of the seasonal coefficients for Fed credit and each component is larger for the Depression years than it had been between 1919 and 1928. The differences are, however, not statistically significant.[29] Thus these data do not support the hypothesis that the Fed was less concerned with seasonal credit and currency demands during the Depression than it had been earlier.

Federal Reserve credit outstanding was subject to large and erratic fluctuations during the Great Depression (see figure 1). In particular, a pronounced change in its behavior appears to have occurred in late 1931, suggesting that inferences drawn from analysis of Fed credit over the entire 1929-33 period might be misleading.

On September 21, 1931, Great Britain stopped converting pounds sterling into gold. Fears that the United States would soon follow Britain off the gold standard led to a large withdrawal of foreign deposits from U.S. banks and a consequent gold outflow. The U.S. monetary gold stock declined 15 percent in the six weeks after Britain's action.[30] Domestic depositors also panicked and converted deposits into currency. Member banks partially offset the reserve drains caused by the gold and currency outflows by selling acceptances to the Fed and by borrowing at the discount window. Federal

[27] If December 1927 is used as the breakpoint, the results are identical to those reported in table 2, except that the first difference of the Fed's acceptance holdings had a stable seasonal pattern.

[28] These are simply the standard deviations of the point estimates of the seasonal dummy coefficients and should not be confused with the standard errors of the coefficient estimates.

[29] The standard deviations for 1928-33 are also larger than those for 1919-27, but the differences are again not statistically significant. The specific test employed is a Wald test of the equality of the variances of the monthly dummy coefficients across the two periods. I thank Joe Ritter for suggesting this test.

[30] Board of Governors of the Federal Reserve System (1943, p. 386).

Reserve credit outstanding rose $959 million (75 percent) between September 16 and October 21.[31] The increase in Fed credit outstanding was not enough, however, to prevent a substantial decline in bank reserves.[32]

Federal Reserve credit outstanding declined somewhat in early 1932 but began to rise in March 1932 with what was then the Fed's largest program of open-market purchases of government securities.[33] From March 1932 to August 1932 the Fed bought more than $1 billion of securities, and these purchases probably explain the atypical mid-year rise in Federal Reserve credit in 1932.

The events of late 1931 and 1932 appear to have altered the pattern of Federal Reserve credit. The evidence reported in table 1 indicates that although Fed credit did not have a statistically significant seasonal pattern between 1929 and 1933 as a whole, it did have one between January 1929 and September 1931. Thus if a change in the seasonal behavior of Federal Reserve credit occurred during the Depression, it was more likely to have occurred after September 1931 than before September 1931. This is important because three of the five financial crises of the Depression occurred before this date and thus cannot be attributed to a possible change in Federal Reserve seasonal policy in September 1931.

Statistical tests to determine whether the seasonal patterns of Federal Reserve credit and its components changed between the January 1919–December 1928 and January 1929–September 1931 periods also suggest no shift in seasonal policy before September 1931. Only in the case of the Fed's acceptance holdings is it possible to reject the null hypothesis that no change in seasonal patterns occurred (see table 2). Comparison of the standard deviations of the seasonal patterns also casts doubt on the view that the Fed was less accommodative of seasonal demands before late 1931 (see table 3).[34]

The period from September 1931 to December 1933 is too short and was too volatile to determine seasonal monetary policy, and the data after 1933 contain no information about accommodation of seasonal demands. The crisis following Britain's departure from the gold standard, the Fed's large open-market purchases in 1932, the collapse of the banking system and the bank holiday in March 1933 all had unusually large effects on Federal Reserve credit. After 1933 gold and currency inflows allowed banks to accumulate large excess reserve holdings, which virtually eliminated the demand for Fed credit. Accordingly, Federal Reserve credit and its components varied little from 1934 until World War II.

THE SEASONAL BEHAVIOR OF INTEREST RATES

This section examines the extent of change in the seasonal behavior of short-term interest rates before and during the Great Depression. By supplying currency and reserves in response to seasonal demands, the Federal Reserve, at least by 1919, had substantially reduced the seasonal amplitude of interest rates. If the Fed reduced its accommodation of seasonal demands during the Depression, it seems likely that interest rates would have become more seasonal.

Table 4 summarizes tests to determine whether three short-term interest rates had statistically significant seasonal patterns.[35] The commercial paper rate had a statistically significant seasonal pattern between 1919 and 1928. The bankers acceptance and call loan rates, however, did not have statistically significant seasonal patterns. None of the rates had a statistically significant seasonal pattern during the Depression, neither during the January 1929–December 1933 period nor during the January 1929–September 1931 period.[36]

Table 5 reports tests of the stability of the seasonal patterns of each interest rate. Although

[31]Board of Governors of the Federal Reserve System (1943, p. 386).

[32]The Fed argued that it lacked sufficient gold reserves to purchase government securities in sufficient quantities to prevent reserves from declining. Friedman and Schwartz (1963) contend that the Fed did have sufficient reserves and in any event had the authority to suspend its reserve requirement temporarily. Wicker (1966), however, argues that Fed officials feared that security purchases would indicate an unwillingness to defend the dollar's value and exacerbate the gold outflow. See Wheelock (1991, 1992) for further discussion.

[33]The Fed's gold reserve requirement was relaxed significantly by the Glass-Steagall Act of 1932, which permitted the Fed to use government securities to partially back its liabilities.

[34]The differences in the standard deviations between the January 1919–December 1928 and January 1929–September 1931 periods are not statistically significant. The findings are not affected if December 1927 is used as the break point.

[35]Specifically, I test the null hypothesis that the coefficients on the monthly dummy variables all equal zero.

[36]The call loan rate did have a statistically significant seasonal pattern between January 1919 and December 1927. The regressions for the level of each rate included an AR(2) error process, and those for the first difference of each rate included an AR(1) error process.

Table 4

Significance of Seasonal Patterns in Short-Term Interest Rates (F-Test Statistics)

	January 1919–December 1928	January 1929–December 1933	January 1929–September 1931
Commercial paper rate	2.94**	1.29	1.23
Call loan rate	1.44	1.35	1.16
Bankers acceptance rate	1.19	1.46	1.29
Change in commercial paper rate	2.78**	0.82	0.88
Change in call loan rate	1.33	1.16	1.01
Change in bankers acceptance rate	0.86	1.10	0.96

* Statistically significant at the .05 level.
** Statistically significant at the .01 level.

Data source: Board of Governors of the Federal Reserve System (1943), pp. 450-51. The data are monthly averages of daily figures.

Table 5

Stability of Seasonal Patterns in Short-Term Interest Rates, December 1928 Breakpoint (F-Test Statistics)

	January 1919–December 1933	January 1919–September 1931
Commercial paper rate	0.92	1.47
Call loan rate	1.46	1.23
Bankers acceptance rate	1.21	1.20
Change in commercial paper rate	1.05	1.73
Change in call loan rate	1.64	1.68
Change in bankers acceptance rate	1.41	1.47

* Statistically significant at the .05 level.
** Statistically significant at the .01 level.

Table 6

Stability of Seasonal Patterns in Short-Term Interest Rates (Standard Deviations of Monthly Dummy Coefficients)

	January 1919–December 1928	January 1929–December 1933	January 1929–September 1931
Commercial paper	0.06	0.16	0.12
Call loan rate	0.24	0.26	0.47
Bankers acceptance rate	0.09	0.26	0.13
Change in commercial paper rate	0.08	0.14	0.12
Change in call loan rate	0.20	0.32	0.43
Change in bankers acceptance rate	0.06	0.22	0.15

no rate had a statistically significant seasonal pattern during the Depression, the null hypothesis that the seasonal pattern was stable is accepted in all cases at conventional levels of significance. Finally table 6 reports the standard deviations of the seasonal dummy coefficients from each regression. For each rate and the change in each rate, the standard deviations are larger for the 1929–33 period than for the 1919–28 period. The standard deviations of the seasonal dummy coefficients are also higher during the January 1929–September 1931 period than during the January 1919–December 1928 period. Thus, as with Federal Reserve credit and its components, comparison of the standard deviations suggests that the interest rates might have fluctuated somewhat more widely across seasons during the Depression than before it. However, none of the changes in the standard deviations is statistically significant.

To put the possible increase in the seasonal pattern of interest rates during the Depression in perspective, figure 6 plots the estimated coefficients on the monthly dummy variables for the call loan renewal rate between 1919 and 1928 and between 1929 and 1933. I use the same scale as in figure 2, where these coefficients are plotted for the 1890–1914 and 1914–33 periods. Comparison of the two figures shows that the increase in the seasonal amplitude of the call loan rate during the Depression was small relative to the decline in amplitude in 1914.[37] For comparison, the standard deviation of the seasonal pattern of the call loan rate between January 1890 and October 1914 is 1.02 (0.67 for the first difference of the call loan rate). For the November 1914–December 1933 period the standard deviation is 0.16 (0.13 for the first difference). The increases in the standard deviations after December 1928 are thus quite small in comparison with the size of the changes in November 1914. The levels of the standard deviations during the Depression are also small in comparison with those in the pre–November 1914 period.[38] The various evidence that interest rates were more seasonal during the Depression is ambiguous. The possible increase in the seasonal pattern of interest rates after 1929, however, seems too small to conclude that unaccommodated seasonal currency and credit demands caused the return of financial crises during the Depression.

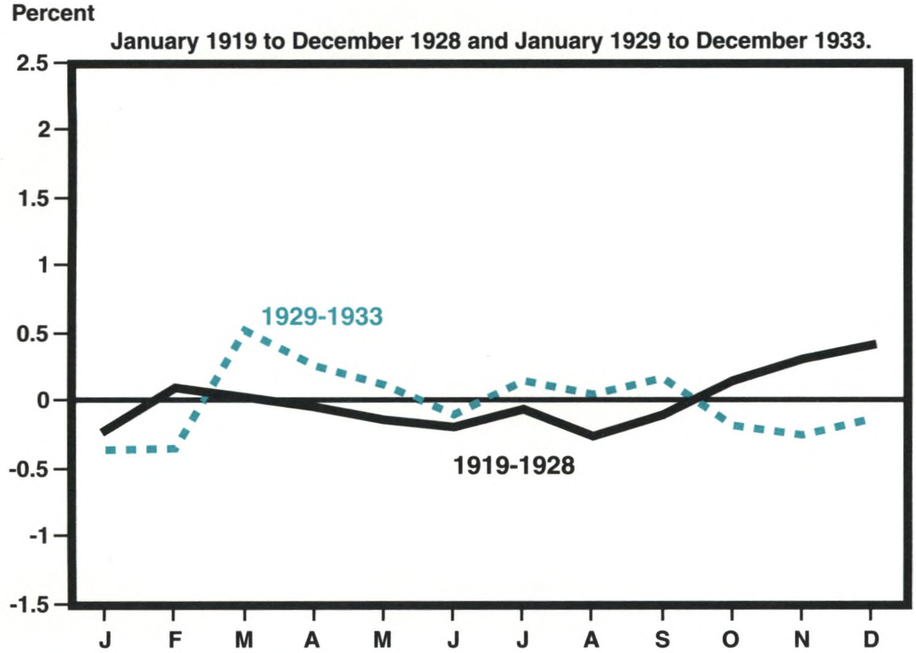
CONCLUSION

Proponents of banking reform in the United States in the early 20th century noted that financial crises tended to occur in months when currency and credit demands reached seasonal peaks. Eliminating crises was a principal goal of the founders of the Federal Reserve System, and they designed methods of accommodating

[37]The months in which the call loan rate reached seasonal peaks between 1929 and 1933 do not coincide with those between 1919 and 1928. The behavior of the call loan rate probably changed markedly after the stock market crash in 1929. Similar plots for the commercial paper and bankers acceptance rates show that the seasonal high and low months for these rates remained the same across periods.

[38]Because the United States did not have an active bankers acceptance market before 1914, it is impossible to make a similar comparison for the bankers acceptance rate.

Figure 6
The Seasonal Pattern of the Call Loan Rate
Monthly Deviations from Annual Mean



currency and credit demands to accomplish that objective. Federal Reserve credit outstanding rose and fell with fluctuations in currency and loan demands, and the Fed's presence appears to have substantially reduced seasonal fluctuations in bank reserves and interest rates. Most important, until 1929 it appeared that the Fed's presence had eliminated financial crises.

The reappearance of financial crises during the Great Depression suggests the possibility that the Fed accommodated seasonal currency and credit demands less in those years than it had between 1914 and 1928. This article shows, however, that the Fed's accommodation of seasonal demands was generally passive, occurring mainly through discount loans and acceptance purchases. There was no seasonal pattern in the Fed's discount and acceptance buying rates. Commercial banks initiated most seasonal extensions of Fed credit, suggesting that changes in demand, rather than deliberate policy decisions, caused any apparent changes in the seasonal pattern of Fed credit. In addition, Federal Reserve credit and its components do not appear to have been less seasonal during the Depression, at least not before September 1931, than they had been during the 1920s. And although the seasonal pattern of interest rates during the Great Depression may have increased slightly, the seasonal fluctuations remained trivial compared with those that occurred before 1914. The Fed's failure to prevent banking panics and declines in bank reserves and the money supply during the Great Depression was a serious error. It appears unlikely, however, that the financial crises of the Great Depression were caused by a change in the seasonal policies of the Federal Reserve System.

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Is The United States Losing Its Dominance in High-Technology Industries?

THE RECENT POLITICAL SEASON once again focused attention on high-technology industries and U.S. competitiveness. Many politicians bemoan the loss of dominance in high-technology industries by the United States.[1] The statistics they use to support their argument include the loss of U.S. global market share in high-technology products, the declining U.S. balance-of-payments surplus in high-technology industries and the persistent balance-of-payments deficit with Japan.

Others argue that the U.S. demise has been greatly exaggerated. They point out that labor productivity in the United States remains greater than in other industrialized countries and that the United States spent more than twice as much in absolute terms as other countries on research and development (R&D).

In fact, the evidence is mixed. Although the United States no longer dominates high-technology industries as it did in the 1950s and 1960s, much of that is due to the economic growth of Japan and Germany rather than to a decline in U.S. high-technology industries. As per capita output in these countries converges, one would also expect indicators in high-technology industries to also begin converging. Some indicators, however, suggest that the United States places a relatively smaller emphasis on R&D and education than do Germany and Japan, the main U.S. competitors in the high-tech arena.[2] As a result, few clear conclusions can be drawn.

The goal of this article is to provide a careful, albeit not comprehensive, analysis of U.S. high-technology industries. First, the paper discusses why high-technology industries are considered valuable to an economy and presents evidence to support these arguments. Next, several performance indicators for high-technology industries in the United States are examined. When possible, these indicators are compared with similar indicators in Japan and Germany. The paper concludes with a discussion of what these indicators predict for the future.

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[1] This attitude can be seen, for example, in the hearing *Factors Affecting U.S. Competitiveness* (see U.S. Congress, 1992) and in articles such as "America's High-Tech Decline," in *Foreign Policy* (see Ferguson, 1989).

[2] All statistics for Germany refer to the former Federal Republic of Germany.

WHAT ARE HIGH-TECHNOLOGY INDUSTRIES?

The term *high tech* is often used, but rarely defined. The Organisation for Economic Co-Operation and Development (OECD) defines high-technology industries as having the following characteristics:

- the need for a strong R&D effort;
- strategic importance for governments;
- very rapid product and process obsolescence;
- high-risk and large capital investments; and
- a high degree of international cooperation and competition in R&D production and worldwide marketing.[3]

Unfortunately, although this definition is important in isolating the general industries, these characteristics are too general to be used to classify firms for statistical purposes. The OECD uses the ratio of R&D expenditure to production costs (the R&D intensity) of an industry, which is the defining characteristic of high-technology for which data are available.[4] According to this criterion, the top six R&D-intensive industries in the main 11 countries are aerospace, office machines and computers, electronics and components, drugs, instruments and electrical machinery.[5] These industries had an average R&D intensity of 11.4 percent in 1980, compared with an average of approximately 4.0 percent for all manufacturing industries.

ARE HIGH-TECHNOLOGY INDUSTRIES MORE IMPORTANT THAN OTHER INDUSTRIES?

The special concern expressed about high-technology industries suggests that these industries provide unique benefits absent from other manufacturing industries. These benefits result from the relatively higher amount of innovation in these industries and the subsequent effect on employment, wages, productivity and economic growth.

High-Technology Industries and Economic Innovation

As discussed in the preceding section, high-technology industries are R&D intensive by definition. Innovation, which takes an invention and transforms it into a product or process that a firm can sell or use, generally results from R&D expenditures. Innovations can be broadly divided into three types: process, final product and intermediate product innovations. A process innovation is one that improves the production technique of a product—for example, Henry Ford's use of the moving assembly line to mass-produce automobiles. This innovation dramatically lowered the cost of producing automobiles and significantly increased auto production. An important distinguishing feature of process innovation is that it directly increases the productivity of one or more factors of production (capital, labor, energy and materials).[6] In fact, experts argue the following: process innovation tends to "have a bigger effect on an industry's own rate of productivity increase than does product R&D."[7]

A final product innovation, in contrast, does not increase productivity directly; instead, it introduces a new product or a variation of an existing product that individuals consume. An example of a final product innovation is the refrigerator, which replaced the icebox. Final product innovations generally have a positive effect on the quality of life—for example, refrigerators involve much less maintenance than iceboxes, leaving more free time for other activities—and have a stimulative effect on output.

[3] OECD (1986). In this paper we consider only high-technology manufacturing industries. Other sectors, such as banking services and insurance, could be considered high tech.

[4] Many variations of this definition are used, in part because some prefer to define high technology in terms of product classes, whereas others (including the OECD) define them in terms of industry classes. Because of data limitations, this paper uses the OECD classification unless stated otherwise.

[5] The main 11 countries, as classified by the OECD, are the United States, Japan, Germany, France, United Kingdom, Italy, Canada, Australia, Netherlands, Sweden and Belgium. The industry classifications differ somewhat from those used by the National Science Board (1991), which classifies the following as high-technology industries: industrial chemicals; drugs and medicines; engines and turbines; office and computing machinery; communication equipment; aerospace; and scientific instruments. This difference is likely due to the fact that the OECD measure is an average over 11 countries in 1980. If a seventh industry were included by the OECD, it would be the automobile industry. The industries classified as high technology according to the OECD classifications have not changed during the course of the sample.

[6] Mansfield proposes using total factor productivity, which is the most general measure of productivity. For a discussion of this measure, see Mansfield (1990).

[7] See Mansfield (1988). Rosenberg (1982) also stresses the importance of improvements to an initial innovation.

Final product innovations, however, do not increase factor productivity directly.[8]

An intermediate product innovation results in a new product that is used to produce another good. In other words, the new product is not consumed by individuals, but rather is used by firms. Productivity increases in industries that use intermediate product innovation. For example, a new machine tool that significantly reduces the time it takes to produce furniture would be considered an intermediate product innovation. Output increases both because the tool industry has a new product and because productivity increases in the furniture industry. Other industries may also benefit if they can adapt the innovation for their own use or if the innovation leads to other innovations. For example, a wood lathe might suggest the possibility of a metal lathe. Innovations that enable a country to produce more output with the same amount of input increase productivity and therefore aggregate output.

Social Benefits from Innovation

Economists have long believed that innovation has a positive effect on economic growth. Schumpeter (1950) argued that the process of creative destruction (the creation of new products that replaced existing products) drives economic growth. Others, such as Solow (1957), estimated the effects of technological change on economic growth. Recently, new growth theorists, such as Romer (1990), Aghion and Howitt (1990) and Grossman and Helpman (1991), have explored the determinants of technological change and its effects on economic growth. They identify endogenous technological spillovers as the primary determinant of economic growth.[9]

Productivity growth is a primary determinant of a country's standard of living. As labor becomes more productive, wages rise.[10] Some economists have argued that technological innovation has a negative effect on employment. The United States, however, has had continued improvements in productivity over the last 100 years, whereas its average unemployment rate has remained essentially unchanged. This suggests that if productivity increases have a negative effect on employment, the effect is not permanent.

Firms invest in R&D because they hope to earn an above-average rate of return on any innovation. The amount of innovation (if any) that results from R&D is always uncertain, so there is no guarantee of a return. As a result, firms expect a greater-than-average rate of return to compensate them for the risk associated with R&D. This return is the cash flow earned over time from an innovation, which includes revenue from product sales, as well as earnings from the leasing or sale of the new technology. The greater the expected return, the greater the incentive to invest in R&D.

The benefits to society from innovation, however, can be substantially larger than the return earned by the innovating firm. The social rate of return measures this benefit. The social rate of return equals the private rate of return plus any technological spillovers, that is, any benefits from an innovation that are not appropriated by the innovator.[11] Because the social rate of return usually exceeds the rate of return the innovator earns, there tends to be a less-than-optimal level of investment in R&D and new technologies.[12] As a result, most countries enact policies that encourage innovation. The most common way is through patent and copyright protection, which improve the likelihood that the innovator will earn an above-normal return on an innovation.[13]

[8]Because the measurement techniques currently used do not measure changes in quality or nonmarket activities (such as household work), output may or may not increase as a result of the innovation. For a discussion of the problems in growth accounting and measuring the value of innovation, see Griliches (1979) or Grossman and Helpman (1991).

[9]In this context, endogenous technical spillovers refer to the gains in knowledge associated with the process of innovation. For a more comprehensive discussion, see the sources cited in the text.

[10]Situations exist that could make some workers worse off, however. An innovation that substitutes capital for labor may reduce employment in the industry adopting the innovation. Although displaced workers may be worse off in the short run, the lower prices that result from an increase in productivity could increase consumers' purchasing power and increase demand in other industries. As a result, employment could rise in those other industries, leaving aggregate employment unchanged. Of course, there are likely adjustment costs associated with the shift in employment. For a discussion of this issue, see Baumol and McLennan (1985).

[11]For a discussion of alternative measures of spillovers, see Griliches (1979).

[12]The possibility of a significant difference between the social and private rate of return exists because it is impossible to control the flow of information generated by an innovation. See Arrow (1962) for a careful discussion of this problem.

[13]See Butler (1990) for a discussion of the relationship between property rights and innovation.

Governments often provide other incentives, both explicit and implicit, to innovate. Tax credits, for example, are offered for R&D in many industrial countries.[14] Many governments also provide funds for R&D, both directly and indirectly, by subsidizing education. In fact, the United States, though it has no explicit industrial policy, publicly finances nearly half of all R&D in the country (an estimated 43.5 percent in 1991).

International Effects of Innovation

The benefits of an innovation, particularly its indirect benefits, are not restricted geographically. To the extent that knowledge generated from innovation is internationally available, countries benefit from all innovation, regardless of where it originates. In general, the gains from innovation are greater in the innovating country than in countries that import the technology because of the increased jobs and higher wages associated with high-technology industries. In addition, the innovating country benefits from earnings on the sale or lease of new technology to other countries. The extent to which a nation benefits from domestic innovation depends greatly on the degree to which that nation is compensated for the innovation-related knowledge and technologies that flow abroad.

Technological innovation, particularly process innovation, has historically traveled slowly because of international capital and labor immobility, as well as linguistic and cultural differences. Mansfield (1984) discusses another reason why process innovation disseminates slowly across borders: Firms are often unwilling to license new technology abroad because it is difficult to control the diffusion of the technology in other countries. This licensing argument should not apply within firms, however. The recent growth of multinational corporations, such as IBM and Toyota, in high-technology industries has significantly increased the pace of technological diffusion internationally.

Regardless of whether impediments to the flow of information or technology exist, however, an innovating country still benefits from innovation through both the private and social returns generated. If process improvements to an initial innovation are made in the innovating country, the benefits of the initial innovation are even greater over time for that country because of increases in productivity.

Evidence Regarding High-Technology Industries

A 1960 National Bureau of Economic Research conference was specifically designed to examine inventive activity, the activity that generates innovation. One of the conference papers discussed the chemical, allied products and pharmaceutical industries between 1947 and 1957 and found that "productivity increases are associated with investment in the improvement of technology and the greater the expenditures for research and development the greater the rate of growth of productivity."[15] More recent studies also found R&D to be an important determinant of innovation and productivity and therefore economic growth.[16] In addition, researchers have found significant differences between the social and private rates of return earned on innovations, supporting the view that the benefits to society from innovation are greater than those appropriated by firms.[17] Unfortunately, these results must be viewed with some skepticism because of measurement and data problems.[18]

Another way high-tech industries benefit a country directly is through their effect on wages and employment. In general, wages might be expected to be higher in innovating industries because producing and developing new products or implementing new processes initially requires a higher skill level. Existing wage and employment data in U.S. high-technology industries support this theory. In 1972, wages in high-technology industries were 16.7 percent higher than wages in all other manufacturing industries. By 1989, wages in high-technology industries were 24.7 percent higher.[19]

U.S. compounded annual employment growth

[14]Some empirical evidence of the effect of tax credits for R&D suggests that their importance in the United States may be modest. See Mansfield (1986) and Cordes (1989). A recent study by Hall (1992) finds stronger support for the effectiveness of R&D tax credits.

[15]See Minasian (1962, p. 94). Recall that increasing the rate of productivity increases economic growth. Output may not necessarily increase if the result of an innovation is a substantial increase in leisure relative to hours worked.

[16]See, for example, Leonard (1971), Mansfield (1980) and Scherer (1982).

[17]See, for example, Mansfield (1981) and Bernstein and Nadiri (1988, 1989).

[18]See Griliches (1979) and Grossman and Helpman (1991) for a discussion of these problems.

[19]This rise in wages could be due to an increase in the demand for skilled labor that exceeds the supply. See Katz and Murphy (1991).

rates between 1970 and 1989 were among the highest in the pharmaceuticals (3.3 percent) and aircraft (3.2 percent) sectors. Employment declined in most lower-technology U.S. industries; the largest declines were in ferrous metals (-2.4 percent) and other transport equipment (-2.5 percent).[20] On average, the compounded annual employment growth rate for all manufacturing industries was 0.2 percent during this period.

Wage differences in high- and low-technology industries can be seen in many industrialized countries. In 1988, wages in high-technology industries for the Group of Seven countries were on average 26.5 percent higher than wages in low-technology industries.[21]

TRENDS IN HIGH-TECHNOLOGY INDUSTRIES

Both the theoretical and empirical evidence of the benefits associated with innovation suggest that R&D-intensive industries are particularly valuable to a country. U.S. high-technology industries dominated the world market for most of the postwar period. In the last two decades, however, this dominance appears to have deteriorated, as reflected by the declining U.S. share of high-technology manufacturing output in the OECD since 1970. This section looks at several indicators of current and future performance in high-technology industries for the United States.[22] The next section compares some of these indicators with those of Japan and Germany.

High-Technology Indicators for the United States

Table 1 shows various statistics on U.S. R&D. High-technology manufacturing output increased by more than 50 percent in 10 years—from 20.0 percent of total manufacturing output in 1980 to 30.4 percent by 1990.[23] This marked increase occurred at the expense of other manufacturing industries. Manufacturing output as a percent of gross domestic product (GDP) remained fairly constant over this period.

Statistics on gross expenditures on R&D (GERD) and business expenditures on R&D (BERD), which are available over a longer period, provide mixed evidence on the behavior of U.S. R&D. Figure 1 shows the components of GERD for 1991, with BERD clearly being the largest component. BERD is divided to show the percent of business R&D that is government funded. Both GERD and BERD have risen in real (constant-dollar) terms since 1975. As a percent of GDP, however, both GERD and BERD have fluctuated since 1970, falling until 1978, rising from 1978 to 1985 and declining since then.[24] Many of the fluctuations have been in defense-related expenditures on R&D. Nondefense spending on R&D as a percent of gross national product (GNP) increased slightly, from 1.6 percent in 1972 to 1.9 percent in 1989.

An important caveat to these numbers results from the problems associated with using an aggregate deflator (such as the GDP deflator) for R&D expenditure. One study found that because of the inadequacies in the deflator used, real R&D expenditures in the period 1969–79 rose only 1 percent—not the 7 percent reported using a standard deflator.[25] In fact, most evidence suggests that R&D costs increase more rapidly than the R&D deflator.[26]

Another indicator of R&D activity can be obtained by examining its components—basic research, applied research and development. According to the National Science Foundation, basic research is "research that advances scientific knowledge but does not have specific commercial objectives."[27]

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[20]The compounded annual growth rate for the aircraft and other transport equipment industry was calculated for the period 1972–89. The other transport equipment category is transport equipment less shipbuilding, automotive and aircraft.

[21]The Group of Seven countries are Canada, France, Germany, Italy, Japan, United Kingdom and United States. Because of data limitations, this wage comparison uses a broader definition of high technology.

[22]Some analysts use patent statistics as an indicator of inventive activity. According to Cockburn and Griliches (1988), however, "Data on R&D expenditures...are stronger measures of input to the process by which firms produce technical innovation than patents are of its 'output.' " In addition, cross-country comparisons of patent statistics are often invalid because of varying standards across countries. Thus patent statistics can be used to compare changes within a country over time, but not across countries.

[23]Table 1 uses the National Science Board definition of high technology.

[24]To get a sense of the magnitudes being examined, a 0.1 percent change in GDP in 1990 equals $5.5 billion.

[25]See Mansfield (1984).

[26]See Bureau of Labor Statistics (1989). Unfortunately, no standard series on an R&D deflator for the United States is available. Available estimates are not consistent with the series shown above. These series were used because they are internationally comparable.

[27]See National Science Board (1991).

Table 1

High-Technology Indicators for the United States

Year	GERD (billions of 1982 dollars)	GERD as a percent of GDP	BERD (billions of 1982 dollars)	BERD as a percent of GDP	Hi-tech manufactures as a percent of total manufacturing output	Manufacturing as a percent of GDP in 1982 dollars[1]
1970	65.27	2.72	43.02	1.79	N.A.	21.12
1975	61.93	2.32	40.79	1.53	N.A.	20.54
1980	74.90	2.39	51.93	1.66	20.0	21.52
1981	78.38	2.45	55.12	1.72	20.7	21.25
1982	81.69	2.62	58.65	1.88	22.4	20.37
1983	87.51	2.71	62.82	1.95	22.9	20.87
1984	95.86	2.78	69.45	2.01	24.5	21.76
1985	104.62	2.93	75.96	2.13	25.5	21.75
1986	106.85	2.91	76.78	2.09	27.0	21.78
1987	108.62	2.87	78.43	2.07	27.9	22.24
1988	112.28	2.83	80.63	2.04	28.7	23.25
1989	114.66	2.82	80.44	1.98	29.6	22.73
1990	114.65	2.80	79.24	1.93	30.4	N.A.
1991	N.A.	2.82	N.A.	1.95	N.A.	N.A.

DEFINITIONS:
GERD—Gross expenditure on research and development
BERD—Business expenditure on research and development
GDP—Gross domestic product
[1]Two different deflators were used for this calculation.

SOURCE: OECD, Science and Technology Statistics (1992); National Science Board; Economic Report of the President.

Applied research is the application of new scientific knowledge to determine how a specific problem or need can be met. For industry this includes specific commercial objectives. Development, on the other hand, is the "systematic use of the knowledge or understanding gained from research directed toward the production of useful materials [and] devices…including design and development of prototypes and processes."[28] Thus research is necessary for invention, but development is required to bring an invention to market. That is, development is required for innovation. Between 1960 and 1990, the allocation of R&D expenditures within these categories remained essentially unchanged.

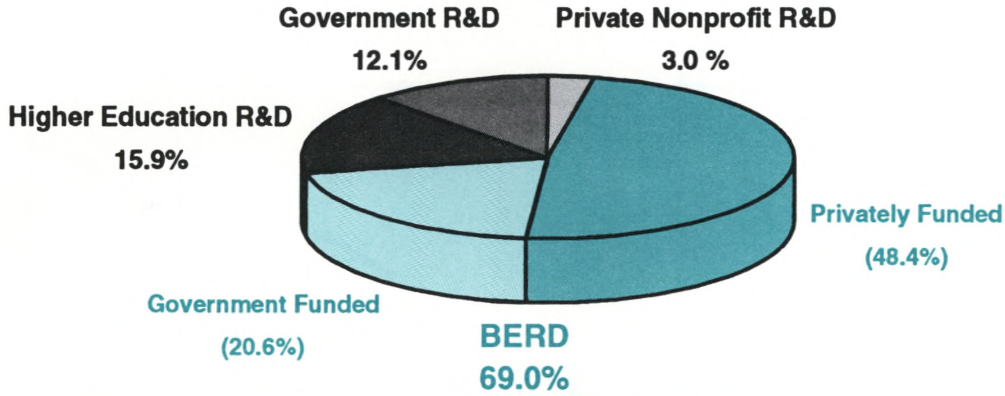
Some commentators have expressed concern about the lack of relative increase in development expenditures. They believe that such expenditures are critical for future technological progress. This argument is particularly relevant concerning new and improved production processes, which have a more direct effect on productivity. For example, the President's Commission on Industrial Competitiveness states the following: "It does [the United States] little good to design state-of-the-art products, if within a short time our foreign competitors can manufacture them more cheaply."[29] According to Mansfield (1988), despite these criticisms there is nothing to "indicate that there was any perceptible increase between 1976 and 1985 in the proportion of [U.S. firms'] R&D expenditures devoted to new or improved processes."

Overall, these statistics appear to contradict the idea that R&D expenditures by U.S. high-technology industries declined in the 1980s. Since 1985, however, R&D as a percent of GDP has been declining. This relative decline may be

[28]See National Science Board (1991).

[29]Cited in Mansfield (1988).

Figure 1
Components of GERD, 1991



a cause for concern, for both productivity growth and performance in high-technology industries.[30]

AN INTERNATIONAL COMPARISON IN HIGH TECHNOLOGY

Much of the concern about U.S. high-technology performance has focused on U.S. indicators relative to those of other countries. This section compares U.S. high-technology performance with that of Japan and Germany.[31] Because of the sheer size of the United States, its total R&D expenditures are much greater than those of Germany or Japan. For example, using OECD purchasing-power parities to convert to dollars, GERD in 1990 was $66 billion in Japan, $28 billion in Germany and $151 billion in the United States.[32]

As a result, the United States can benefit from the additional resources it can spend on R&D, to the extent that its R&D is at least as productive as R&D in the other two countries. Several researchers have expressed concern regarding the productivity of U.S. R&D, particularly in regard to other countries.[33] One reason for this is the high percentage of R&D funded by the government. Studies have found that government-funded private R&D is less productive than privately funded business R&D.[34]

Figures 2 and 3 show GERD and BERD as a percent of GDP for the three countries. Throughout most of the last 20 years, the United States has had higher GERD/GDP and BERD/GDP ratios than Germany and Japan.[35] From 1964 to 1990, Japan and Germany each increased its GERD as a percent of GDP by approximately 100 percent. From 1980 to 1990 (1981 for Germany), however,

[30]The effects of R&D are estimated to have about a two-year lag on productivity. A longer lag is associated with basic research (Bureau of Labor Statistics, 1989).

[31]In 1989, the average expenditure on GERD as a percent of GDP for these three countries was 2.9 percent, compared with the OECD average for reporting countries, which was 1.7 percent. This statistic excludes Australia, Belgium and Portugal. If they were included, the number would likely be slightly lower.

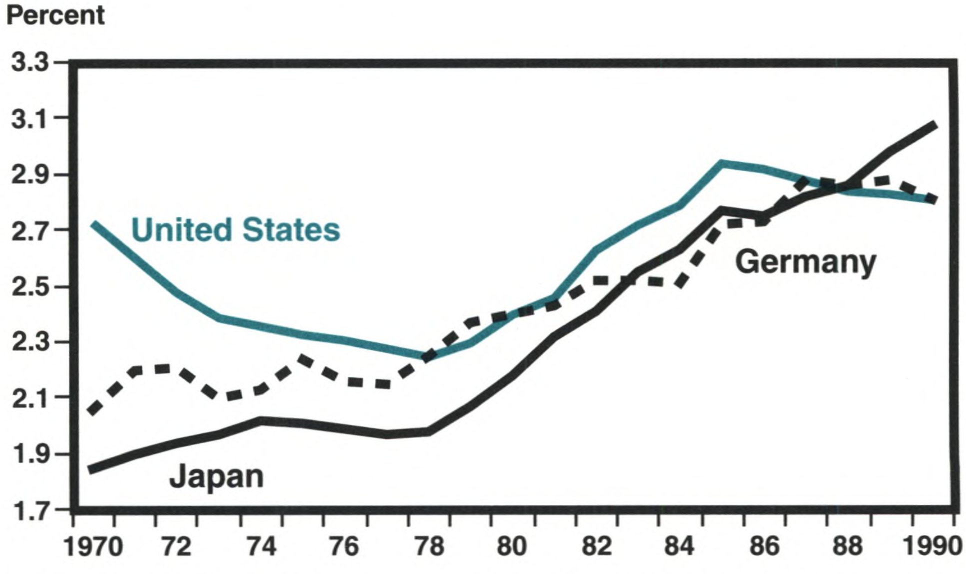
[32]Purchasing-power parities measure the number of U.S. dollars required in each country to buy the same representative basket of final goods and services that cost $100 in the United States.

[33]See Scherer (1982) and Mansfield (1988). Mohnen, Nadiri and Prucha (1986) compared the rate of return on R&D in the three countries and also found that the return was lowest in the United States.

[34]See Griliches (1986, 1987).

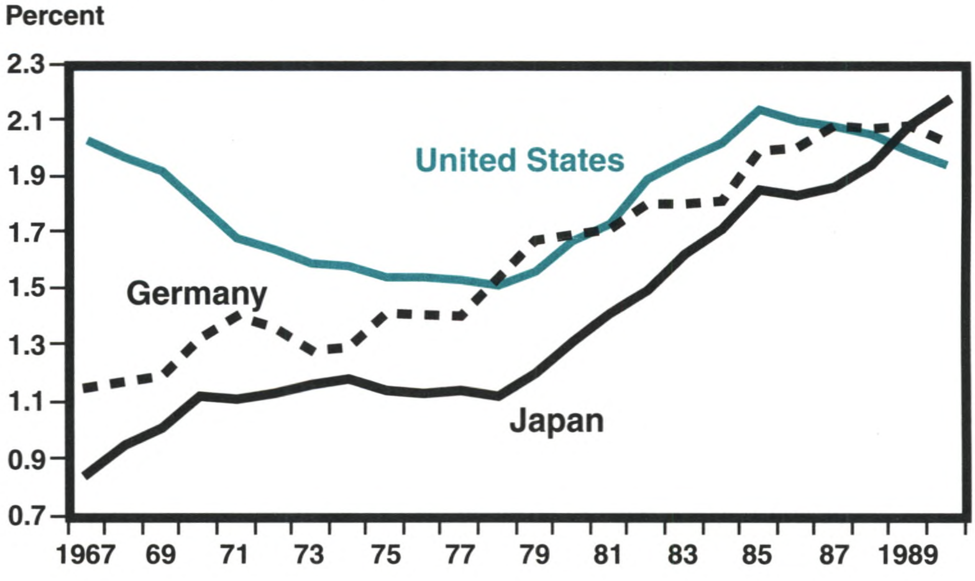
[35]Because of the problems associated with using standard deflators for R&D, these numbers could be somewhat misleading. If, for example, R&D costs rose faster in Japan relative to GDP than in the other two countries, the actual ratio for Japan would be relatively lower. The only attempt to calculate R&D deflators across countries was done by the OECD (1979) for the period 1967–75. The results suggested that the R&D deflator moved together for these countries. Unfortunately, the deflators for Japan and Germany were not directly comparable, and a deflator was not calculated for the United States. As a result, it is difficult to predict whether the price of R&D would move differently across countries. A worldwide program has attempted to produce international comparisons of variables in the National Income and Product Accounts across countries. See Kravis and Lipsey (1990) for a summary and update on this program.

Figure 2
GERD as a Percent of GDP



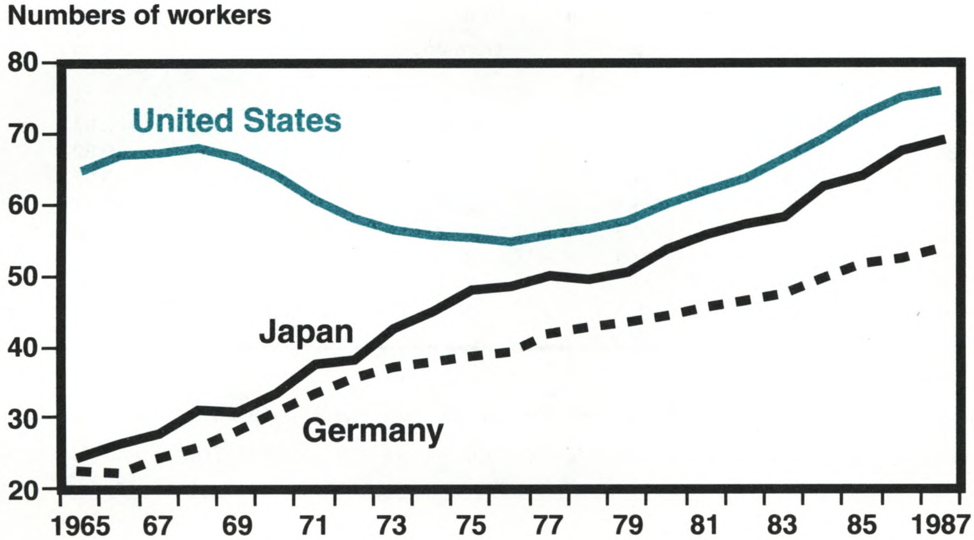
U.S. data for 1971 and German data for 1980 were not available.

Figure 3
BERD as a Percent of GDP



German data for 1976, 1978, and 1980 were not available.

Figure 4
Scientists and Engineers Working in R&D per 10,000 Labor Force



The figure for Germany increased in 1979 because the 1979 survey includes small and medium enterprises not surveyed in 1977.

Data for Germany in 1978, 1980, 1982, 1984, 1986, and 1987 are estimated.

SOURCE: National Science Board, 1991.

Japan's increase in GERD as a percent of GDP was 40.8 percent, much higher than the 15.6 percent increase in Germany or the 17.2 percent increase in the United States. BERD as a percent of GDP also increased steadily in Japan and Germany over the last 23 years, whereas U.S. spending fluctuated during the same period. By 1990 the ratios were essentially equal in the three countries.

The lack of variability in other countries could be attributed to the low level of military spending in these other countries. For example, in 1989, 28.9 percent of U.S. R&D was defense related, compared with 4.6 percent of Germany's R&D and less than 1.0 percent of Japan's R&D.

Another measure of innovative activity is the number of science and engineering (S&E) personnel relative to the total workforce (see figure 4). Throughout the sample, the United States has employed more S&E personnel per 10,000 workers than either Germany or Japan. Although the number of S&E workers relative to the labor force has risen on average in all three countries, the increase has been substantially greater in Japan and Germany. As a result, this difference among the three countries has narrowed considerably.

The technological balance of payments (shown in table 2) measures the difference between receipts and payments related to earnings on technology and is an indicator of the degree to which a country is an exporter or importer of technology. This measure includes revenues associated with the use of patents, licenses, trademarks, designs, inventions, know-how and closely related technical services. This balance has been steadily increasing for the United States since 1969 (the first year data are available), showing that earnings on U.S. technological exports continue to significantly exceed U.S.

Table 2

International Comparisons in High-Technology Indicators

	High-tech manufactures' share of total manufacturing output[1] (percent)			Technology balance of payments[2] (billions of U.S. dollars)		
Year	U.S.	Japan	Germany	U.S.	Japan	Germany
1971	N.A.	N.A.	N.A.	2.30	−0.44	−0.32
1975	N.A.	N.A.	N.A.	3.83	−0.37	−0.45
1980	20.0	16.3	16.1	6.36	−0.32	−0.56
1985	25.5	24.6	20.4	5.10	−0.27	−0.65
1986	27.0	26.4	20.8	6.19	−0.17	−0.55
1987	27.9	29.5	20.9	7.70	−0.32	−0.60
1988	28.7	32.9	21.3	8.80	−0.32	−0.65
1989	29.6	34.5	20.6	9.57	0.00	−1.05
1990	30.4	35.1	20.3	12.65	−0.17	−0.93

[1]National Science Board definition.

[2]OECD purchasing-power parties are used to convert yen and deutsche marks to dollars.

SOURCE: National Science Board, Science and Engineering Indicators (1991); OECD, Science and Technology Statistics.

payments for technological information. Japan and Germany have both, on average, increased their exports of technology during this period. By 1989 Japan exported as much technology as it imported, suggesting that, contrary to popular perception, Japan is becoming an innovator in its own right.

The increased importance of high-technology industries in these countries can also be seen by looking at international comparisons in high-technology indicators (see table 2).[36] High-technology manufactures as a percent of total domestic manufacturing output rose by more than 100 percent in Japan between 1980 and 1990. This ratio increased in the United States and Germany, although by significantly less—52.0 percent and 26.1 percent, respectively.

In the last 10 years, the market for high-technology products in OECD countries has increased by 117 percent in constant (1980) dollars. Output in high-technology industries rose in Japan, Germany and the United States during this period. However, despite the 92.9 percent increase in the value of its high-technology output from 1980 to 1990, the U.S. share of global high-technology manufacturing declined by 11.1 percent. Germany's share declined 20.3 percent during this period as well, and the share of the remaining OECD countries as a whole declined 13.6 percent (see table 3). As these countries lost market share, Japan's market share increased 58.7 percent. Thus although the United States remains the major producer of high-technology goods, it no longer dominates all high-technology industries.

The composition of high-technology goods production also changed markedly during these 10 years. For example, the U.S. share of global production of office and computing machinery fell by 15.2 percentage points, whereas Japan's share rose an offsetting 15.5 percentage points. Similarly, the U.S. share of radio, television and communications equipment declined 6.0 percentage points from 1980 to 1990, whereas Japan's share of this global market increased by 15.6 percentage points. This suggests that the United States has faced increased competition in these industries. On the other hand, its position in industrial chemicals, drugs and medicines remains essentially unchanged, and its market share of scientific instruments increased somewhat.

[36]The rest of this section uses the National Science Board definition of high-technology industries. Because the board changed from the OECD definition in its 1991 report, a longer consistent time series for these variables is not available.

Table 3

Country Share of Global Market for High-Tech Manufactures, by Industry: 1980–90 (in percent)

	1980	1981	1982	1983	1984	1985	1986	1987	1988 (est.)	1989 (est.)	1990 (est.)
High-tech manufactures											
United States	40.4	39.5	38.9	37.8	37.9	36.3	36.9	37.5	37.0	36.0	35.9
Japan	18.4	19.7	20.4	21.6	23.3	23.6	23.4	25.1	26.5	28.4	29.2
Germany	11.8	11.7	11.8	11.8	11.3	12.0	11.5	10.5	10.1	9.5	9.4
Industrial chemicals											
United States	32.7	33.1	29.8	29.2	28.0	25.8	28.5	31.4	31.2	32.2	32.5
Japan	16.1	14.4	15.3	14.0	14.1	13.4	12.1	13.1	12.7	13.4	14.1
Germany	16.2	16.9	17.9	19.1	19.5	20.4	20.4	18.5	18.7	18.8	18.4
Drugs and medicines											
United States	29.6	29.6	30.3	30.3	30.4	30.0	30.4	31.4	31.4	30.8	29.2
Japan	21.2	21.7	22.1	22.0	21.2	20.7	20.4	19.9	20.1	20.1	20.3
Germany	13.1	13.1	12.5	12.5	12.7	12.3	12.1	11.4	11.5	11.4	10.9
Engines and turbines											
United States	44.2	37.9	35.0	33.0	35.4	34.8	35.4	35.4	35.8	35.2	34.9
Japan	18.4	16.1	17.9	18.8	18.0	17.0	14.9	15.7	15.5	15.8	15.3
Germany	11.3	9.9	9.0	9.4	10.3	11.2	10.9	11.2	10.7	10.8	11.6
Office and computing machinery											
United States	50.0	49.0	49.1	45.2	44.0	39.6	37.8	38.1	37.3	35.6	34.8
Japan	22.0	23.0	24.0	27.2	27.5	30.2	30.8	31.8	33.3	34.6	37.5
Germany	6.5	7.4	7.0	7.0	7.4	8.3	8.0	7.1	6.6	5.5	5.4
Radio, TV and communication equipment											
United States	36.6	34.8	35.0	34.0	33.8	32.9	32.8	32.3	31.5	29.9	30.6
Japan	26.4	30.5	30.7	32.2	35.5	34.0	33.0	36.5	39.3	42.9	42.0
Germany	12.0	11.4	11.4	11.1	9.8	11.3	11.6	10.3	9.6	9.5	10.0
Aircraft											
United States	57.6	56.4	56.6	55.8	58.7	57.9	59.5	58.7	59.2	56.4	55.9
Japan	2.2	2.4	2.3	2.4	2.5	2.9	2.5	2.8	3.2	3.6	3.6
Germany	4.8	5.3	6.0	5.4	5.0	5.0	4.4	4.6	4.7	4.6	4.8
Scientific instruments											
United States	49.1	49.0	50.5	50.0	50.4	48.4	48.4	50.8	51.5	52.7	53.4
Japan	17.6	19.2	18.1	19.0	19.0	19.7	18.9	18.1	16.2	16.1	15.4
Germany	11.4	10.8	10.2	9.8	9.8	10.8	11.1	11.1	11.4	10.8	11.1

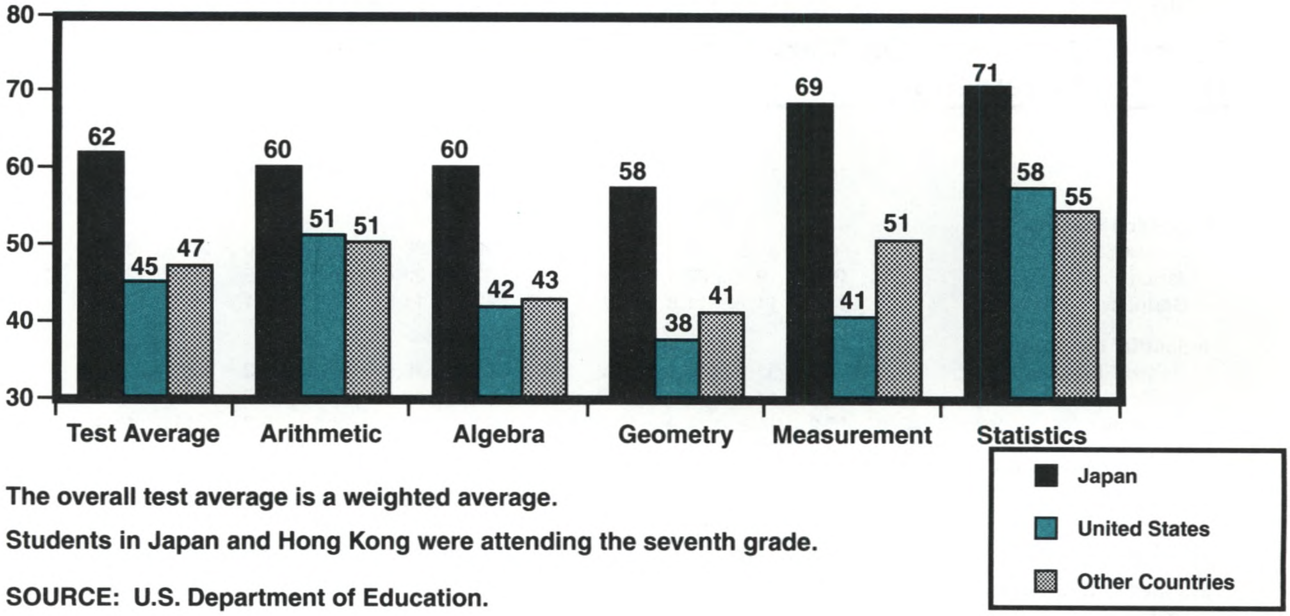
NOTES: Total shipments by OECD countries are used as a proxy for global output. Shares represent each country's shipments as a percentage of OECD shipments. Germany refers to the former Federal Republic of Germany.

SOURCE: See National Science Board (1991).

Figure 5

International Comparisons in Education

Average mathematics test scores for eighth-grade students, 1981-1982



The overall test average is a weighted average.

Students in Japan and Hong Kong were attending the seventh grade.

SOURCE: U.S. Department of Education.

Whether the United States will continue to be a world leader in high-technology manufacturing is unclear. Although its relative position in high-tech manufacturing has slipped in the past decade, so have those of many other industrialized countries, with Japan gaining most of the lost market share.[37] On average, the U.S. decline was less than those of European countries. Furthermore, it seems unlikely that any country could maintain the degree of dominance that the United States enjoyed in the early postwar period. Even if the United States had continued to increase its high-tech manufacturing at the same rate as in the postwar period, the entry of other countries into high-technology industries would have guaranteed a loss of market share for the United States. Hence the recent loss of world market share itself is not cause for alarm, given the significant output increase in U.S. high-tech industries during the period.

WHAT IS LIKELY FOR THE FUTURE?

Concern remains that hidden in these trends is the future decline of U.S. high-technology industries. Given the higher skills necessary for both employment in high-technology industries and success in R&D, the education level and scholastic performance of U.S. students (relative to those in other countries) is coming under increased scrutiny. A possible indicator of future performance in high-technology industries, educational performance comparisons, is presented in figures 5 and 6. International education comparisons are extremely difficult because of the differences in educational systems. As a result, these statistics should be viewed only as suggestive.[38]

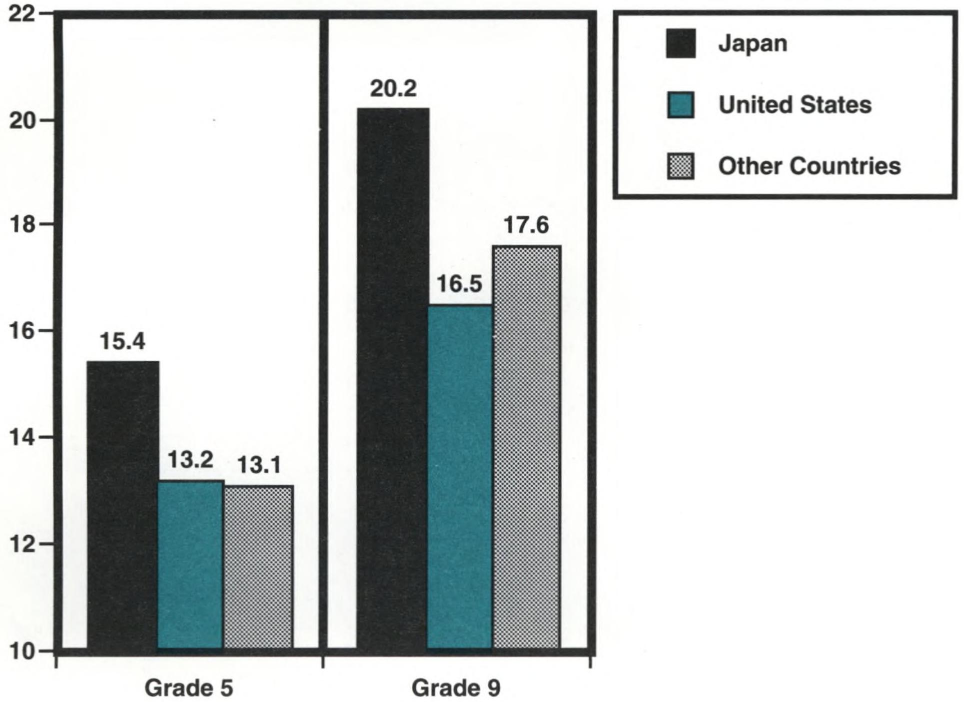
An international assessment study comparing students from 18 countries found significant

[37]The United Kingdom substantially increased its share of several high-technology industries and its share overall. Data were not presented for the United Kingdom, however, because the R&D series is incomplete and its R&D expenditure as a percent of GNP is significantly lower than for the countries presented (2.0 in 1989).

[38]For the complete comparisons, see original source.

Figure 6
International Comparison in Education

Science test scores for fifth- and ninth grade students—1983-1986



Tests were administered between 1983 and 1986. The average age in years and months is 10:9 for fifth-grade students and 14:10 for ninth-grade students.

SOURCE: International Association for the Evaluation of Educational Achievement.

differences in the performances of U.S. and Japanese students (Germany did not participate).[39] In fact, the U.S. ranking in geometry was eleventh, and its ranking in measurement was twelfth out of the 12 industrialized countries that participated in the tests. In a different study of science test scores for 10- and 14-year-olds, the U.S. students ranked significantly lower than Japanese students.[40] On average, U.S. students generally did poorer than students from other countries.[41]

Several other studies that focus only on U.S. students have found a general decline in their performance in mathematics and science during the 1970s with some improvement in the 1980s.[42] These statistics suggest that the United States may have difficulty meeting the demand for the jobs associated with high-technology industries because these jobs require an increasingly high level of skill.

Table 4 shows the percentage of higher education degrees awarded to U.S. citizens and permanent U.S. residents that were awarded in science and engineering. The percentage of master's degrees and doctorates in science and

[39]The participating countries were Belgium, Canada, England and Wales, Finland, France, Hong Kong, Hungary, Israel, Japan, Luxembourg, Netherlands, New Zealand, Nigeria, Scotland, Swaziland, Sweden, Thailand and the United States.

[40]The participating countries were Austrailia, Canada (English), England, Finland, Hong Kong, Hungary, Italy, Japan, South Korea, Netherlands, Norway, Philippines, Poland, Singapore, Sweden, Thailand and the United States.

[41]Unfortunately, only a small amount of research has occurred in this area. For a discussion of several other comparative studies, which reached similar conclusions, see National Science Board (1991), OECD (1992) and the November 21, 1992, issue of *The Economist.*

[42]See, for example, National Science Board (1991, 1989).

Table 4

Degrees Awarded to U.S. Citizens and U.S. Permanent Residents in the United States for Selected Years

	1977	1979	1981	1985	1987	1989	1990
Baccalaureate degrees in science and engineering as a percent of total	40.1	39.8	39.1	35.5	35.1	33.7	33.6
Science and engineering baccalaureate degrees awarded per 100,000 population	166.2	161.5	157.0	142.5	140.2	136.1	138.3
Total baccalaureate degrees awarded	912,484	913,487	924,246	961,619	974,940	1,003,714	1,035,598
Master's degrees in science and engineering as a percent of total	25.0	25.0	25.3	25.9	26.6	25.8	25.1
Per capita science and engineering master's degrees awarded per 100,000 population	34.1	31.4	30.2	28.2	28.6	28.9	28.9
Total master's degrees awarded	300,896	282,648	274,740	260,261	262,268	278,927	290,345
Doctorate degrees in science and engineering as a percent of total	53.2	54.0	54.8	56.2	56.6	57.7	57.2
Per capital science and engineering doctorate degrees awarded per 100,000 population	6.6	6.4	6.3	5.8	5.7	5.8	5.9
Total doctorate degrees awarded	27,487	26,784	26,342	24,694	24,561	25,024	25,844

SOURCE: National Science Foundation.

engineering being awarded has increased since 1977. On a per capita basis, however, the number of people getting bachelor's and advanced degrees, both in science and engineering and overall, has generally declined, although some improvement has occurred in the last three years.

Another factor that could play a pivotal role in determining the future of R&D investment in the United States is the recently proposed cuts in military spending. As previously discussed, defense-related expenditures on R&D in 1987 were responsible for 65.5 percent of government-funded R&D and 28.9 percent of total R&D in the United States, which is a significantly larger portion than allocated in other countries. Analysts are concerned that a loss of these funds could cause the U.S. share of global output in high technology to continue its decline. Of course, firms or the government could replace all of the military-funded R&D with other R&D funding.[43] A significant decline in R&D expenditure, however, would likely reduce U.S. innovation both absolutely and relative to other countries and could have an adverse effect on U.S. high-technology industries. Legislation has already been proposed in Congress to ensure government's commitment to R&D; one proposal uses defense-funded scientists to develop commercial technologies.[44] At this point, determining either the magnitude of any R&D cuts or the response of the nondefense government and private sectors to these cuts is essentially impossible.

[43]For a study that examined the effect of a cut in federally financed R&D in the energy sector, see Mansfield (1984).

[44]See, for example, the National Defense Authorization Act (1992).

CONCLUSION

High-technology industries have a significant positive effect on economic growth because of their high rates of innovation. During the 1980s, production of high-technology products in OECD countries increased by 117 percent. The continued increase in resources devoted to R&D in Germany, Japan and the United States reflects the importance of high-technology industries. Although high-technology output as a percent of GDP has decreased somewhat in the United States during the last few years, it remains higher than it was in 1970. During this period, Japan and Germany, which initially spent a much smaller portion of GDP on R&D than did the United States, had significant growth in R&D expenditures and high-technology output. Thus although the commitment of resources for R&D relative to the size of each economy has essentially equalized in the three countries, the United States still spends the most in absolute terms on R&D and has the largest market share in high-technology industries. The extent to which the United States can exploit its size advantage depends on how productive U.S. R&D is relative to these other countries. Unfortunately, little research has been conducted on this topic, so although some experts have expressed concern about the productivity of U.S. R&D, evidence remains inconclusive. This important area of research has yet to be fully explored. Nevertheless, the increasing importance of high-technology industries suggests that a continued presence in these industries will help maintain high-wage/high-skill jobs and continued economic growth for the United States.

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An Extended Series of Divisia Monetary Aggregates

THE CONVENTION IN monetary economics has been to create monetary aggregates by simply adding together the dollar amounts of the various financial assets included in them. This is the simple-sum method of aggregation. This procedure has been criticized because such monetary aggregates are essentially indexes that weight each component financial asset equally, a practice that is economically meaningful only under special circumstances.

A number of alternative indexes of monetary aggregates have been developed recently. The most well known are the Divisia monetary aggregates developed by Barnett (1980). This article reviews the theoretical basis for monetary aggregation and presents series of Divisia monetary aggregates for an extended sample period. The behavior of the simple-sum aggregates and their Divisia counterparts are compared over this period.

THE THEORETICAL BASIS FOR MONETARY AGGREGATION[1]

Simple-sum aggregation stemmed directly from the classical economists' notion that the essential function of money is to facilitate transactions, that is, to serve as a medium of exchange. Assets that served as media of exchange were considered money and those that did not, were not. By this definition only two assets, currency and demand deposits, were considered money. Both assets were non-interest bearing, and individuals

[1]The discussion in this section is based on consumer demand theory. This may not be a serious limitation. For example, Feenstra (1986) has shown that money in the utility function is equivalent to other approaches. These approaches assume, however, that all of the costs and benefits of money are internalized, and it is commonly believed that there are externalities to the use of money in exchange (see Laidler [1990]).

were free to alter the composition of their money holdings between currency and demand deposits at a fixed one-to-one ratio. Consequently the monetary value of transactions was exactly equal to the sum of the two monies.[2] Simple-sum aggregation was a natural extension of both restricting the definition of money to non-interest-bearing medium-of-exchange assets and of the fixed unitary exchange rate between the two alternative monies.[3]

In consumer demand theory, simple-sum aggregation is tantamount to treating currency and demand deposits as if they are perfect substitutes. Currency and demand deposits, however, are not equally useful for all transactions, so this assumption was clearly inappropriate. But, simple-sum aggregation of those two monetary assets was still appropriate because the assets were non-interest bearing and exchanged at a fixed one-to-one ratio. Consequently individuals would allocate their portfolio of money between the two assets until they equalized the marginal utilities of the last dollar held of each. Under these conditions, simple-sum aggregation is appropriate if it is also assumed that each agent is holding his equilibrium portfolio.

The recognition that non-interest-bearing demand deposits may have paid an implicit interest weakened the theoretical justification for simple-sum aggregation. A more serious blow to simple-sum aggregation, however, was dealt by a shift in monetary theory to emphasizing the store-of-value function of money.[4] That an asset could not be used directly to facilitate transactions was no longer a sufficient condition for excluding it from the definition of money. Instead, the asset approach to money emphasized money's role as a temporary abode of purchasing power that bridges the gap between the sale of one item and the purchase of another. Currency and checking accounts are money because they are both media of exchange and temporary abodes of purchasing power. Non-medium of exchange assets are superior to currency and non-interest-bearing checking accounts as stores of value because they earn explicit interest. This superiority typically increases with the length of time between the sale of one item and subsequent purchase of another because the cost of getting into and out of such assets and the medium of exchange assets is thought to be small and *not* proportional to the size of the transaction.

This shift in emphasis in monetary theory dramatically expanded the number of assets that were considered money and the number of alternative monetary aggregates proliferated.[5] Nonetheless, the method of aggregation remained the same—simple-sum aggregation.

As more financial assets came to be considered money, it became increasingly clear that it was inappropriate to treat these assets as perfect substitutes. Some financial assets have more "moneyness" than others, and hence they should receive larger weights. In what appears to be the first attempt at constructing a theoretically

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[2]This need not be true for the economy as a whole when measured over a sufficiently long time interval. In this case the amount of each form of money multiplied by its turnover velocity will equal total expenditures. This is the basis for the velocity of the demand for money. Fisher (1911) explicitly recognized that turnover velocities of currency and checkable deposits would likely be different. He circumvented this problem by assuming that there was an optimal currency-to-deposit ratio that would be a function of economic variables. Given these variables, the demand for the two alternative monetary assets was taken to be strictly proportional. Moreover, because individuals were free to adjust their money holdings between currency and checkable deposits quickly and at low cost, Fisher argued that the actual ratio would deviate from the desired ratio for only short periods. For some recent evidence that the actual currency-to-deposit ratio might be determined by the policy actions of the Federal Reserve, see Garfinkel and Thornton (1991). The possibility that currency and checkable deposits have different turnover velocities is the basis for Spindt's (1985) weighted monetary aggregate, MQ.

[3]There is an issue of whether the fixed ratio was endogenous, from either the perspective of supply or demand, or the result of arbitrary legal restrictions. From the demand side, this would require that these assets be perfect substitutes for all transactions. From the supply side, Pesek and Saving (1967) argued that the one-to-one exchange rate was a natural outcome of competitive pressures in the banking industry. Whether the fixed one-to-one ratio is the endogenous outcome of a free market economy or is simply due to legal restrictions remains controversial.

Of course today some checkable deposits earn explicit interest. Consequently such deposits are a better store of wealth than currency. They are also a preferable medium of exchange for some, but not all, transactions.

[4]There has been a difference of opinion about the degree of emphasis that should be placed on the asset and transactions motives for holding money. Indeed, Laidler (1990, pp. 105–6) has noted that "...the most extraordinary development in monetary theory over the past fifty years is the way in which money's means-of-exchange and unit-of-account roles have vanished from what is widely regarded as the mainstream of monetary theory."

Broaching the medium-of-exchange line of demarcation between money and non-money assets also gave rise to an extensive literature on the empirical definition of money. For a critique of this literature and the idea of distinguishing between monetary and non-monetary assets based on the concept of the temporary abode of purchasing power, see Mason (1976).

[5]At one point the Federal Reserve published data on five alternative monetary aggregates.

preferable alternative to the simple-sum monetary aggregate, Chetty (1969) added various savings-type deposits, weighted by estimates of the degree of substitution between them and the pure medium of exchange assets, to currency and demand deposits. Larger weights were given to assets with a higher estimated degree of substitution.[6]

Divisia aggregation, which also relies on consumer demand theory and the theory of economic aggregation, treats monetary assets as consumer durables such as cars, televisions and houses. They are held for the flow of utility-generating monetary services they provide. In theory, the service flow is given by the utility level. Consequently the marginal service flow of a monetary asset is its marginal utility. In equilibrium, the marginal service flow of a monetary asset is proportional to its rental rate, so the change in the value of a monetary asset's service flow per dollar of the asset held can be approximated by its user cost. The marginal monetary services of the components of Divisia aggregates are likewise proxied by the user costs of the component assets. The user cost of each component is proportional to the interest income foregone by holding it rather than a pure store-of-wealth asset—an asset that yields a high rate of return but provides no monetary services. Currency and non-interest-bearing demand deposits have the highest user cost because they earn no explicit interest income. Consequently they get the largest weights in the Divisia measure. On the other hand, pure store-of-wealth assets get zero weights.[7]

The object of a Divisia measure is to construct an index of the flow of monetary services from a group of monetary assets, where the monetary service flow per dollar of the asset held can vary from asset to asset.[8] Applying an appropriate index number to a group of assets is not sufficient, however, to get a correct measure of the flow of monetary services. The index must also be constructed from a set of assets that can be aggregated under conditions set by consumer demand theory. The objective of economic aggregation is to identify a group of goods that behave as if they were a single commodity. A necessary condition for this is block-wise weak separability. Block-wise weak separability requires that consumers' decisions about goods that are outside the group do not influence their preferences over the goods in the group whatsoever.[9] If this condition is satisfied, consumers behave just as though they were allocating their incomes over a single aggregate measure of monetary services and all other commodities to maximize their utility. Their total expenditure on monetary services is subsequently allocated over the various financial assets that provide such services.

The Divisia index generates such a monetary aggregate. Moreover, in continuous time it has been shown to be consistent with any unknown utility function implied by the data. In discrete time the Divisia index is in the class of superlative index numbers. Simple-sum indexes, on the other hand, do not have this desirable property. Thus they have no basis in either consumer demand theory or aggregation theory.[10]

In principle, all financial assets other than pure store-of-wealth assets provide some monetary services. Which assets can be combined into a meaningful monetary aggregate is an empirical

[6]Chetty's work was motivated by the Gurley/Shaw hypothesis and the general lack of agreement in the empirical findings of Feige (1964) and others about the degree of substitutability between money and near-money assets. Gurley and Shaw (1960) suggested that the effectiveness of monetary policy was limited because of the high degree of substitutability between money (currency and demand deposits) and near-money (various bank and nonbank savings-type accounts) assets. Subsequent research has tended to support Feige's finding of a relatively low degree of substitutability between transactions media and liquid, non-medium-of-exchange assets. See Fisher (1989) for a survey of much of this literature.

[7]There does not appear to be agreement about what constitutes the best proxy measure for the theoretical pure store-of-wealth asset. Barnett, Fisher and Serletis (1992, p. 2,093) state the following, "The benchmark asset is specifically assumed to provide no liquidity or other monetary services and is held solely to transfer wealth intertemporally. In theory, R (the benchmark rate) is the maximum expected holding period yield in the economy. It is usually defined in practice in such a way that the user costs for the monetary assets are (always) positive." Parentheses added. The Baa bond rate, or the highest rate paid on any of the component assets when the yield curve becomes inverted, has frequently been used to construct Divisia aggregates.

[8]See Barnett, Fisher and Serletis (1992) and Yue (1991a and b) for more detailed analyses of issues in monetary aggregation.

[9]Technically the marginal rates of substitution between any two goods inside the group must be independent of the quantities of the goods consumed that are outside of the group.

[10]Fisher (1922) was especially critical of the simple-sum index in his extensive analysis of index numbers. In particular, Fisher argued that simple-sum aggregates cannot internalize pure substitution effects associated with relative price changes. Thus changes in utility, which should occur only as a result of the income effect associated with relative price changes, occur in simple-sum aggregates because of both income and substitution effects.

issue because economic theory does not tell us which group of assets satisfies the condition of block-wise weak separability. Unfortunately, the most widely used test for weak separability is not powerful.[11] Consequently, it has been common simply to create Divisia indexes under the maintained hypothesis that the assets that compose the aggregate satisfy this condition. Thus the issues of the appropriate method of aggregation and the appropriate aggregate have been treated separately.[12]

SIMPLE-SUM AND DIVISIA MONETARY INDEXES

A simple-sum monetary aggregate is a measure of the *stock* of financial assets that compose it, whereas a Divisia monetary aggregate is a measure of the *flow* of monetary services from the *stocks* of financial assets that compose it.[13] For this reason alone, the methods of measurement are quite different. Simple-sum aggregates are obtained by simply adding the dollar amounts of the component assets. On the other hand, Divisia monetary aggregates are obtained by multiplying each component asset's growth rate by its share weights and adding the products. A component's share weight depends on the user costs and the quantities of all component assets.[14] Specifically, the share weight given to the j^{th} component asset at time t is its share of total expenditures on monetary services; that is,

$$S_{jt} = u_{jt}\, q_{jt} / \left(\sum_{j=1}^{n} u_{jt}\, q_{jt}\right),$$

where q_j denotes the nominal quantity of the j^{th} component asset, u_j denotes the j^{th} component's user cost and n denotes the number of component financial assets. The user cost is equal to $(R\text{-}r_j)p/(1+R)$, where R is the benchmark rate (that is, the rate on the pure store-of-wealth asset), r_j is the own rate on the j^{th} component, and p is the true cost-of-living price index that cancels out of the numerator and denominator of the shares. The growth rate of the i^{th} Divisia monetary aggregate, GDM_i, is given by

$$GDM_i = \sum_{j=1}^{n} [(S_{jt} + S_{jt-1})/2]\, g_{jt},$$

where g_{jt} is the growth rate of q_{jt}.[15]

A Comparison of Simple-Sum and Divisia Monetary Aggregates

Because the Divisia aggregates are an alternative to the conventional simple-sum aggregates, it is instructive to compare them. When constructing data in this section, the authors used an extension of the Farr and Johnson (1985) method. The Appendix presents details of the construction of the Divisia monetary aggregates used here.

A Divisia monetary index is an approximation to a nonlinear utility function. Because it is an index, the level of utility is an arbitrary unit of measure; the level of the index has no particular meaning.[16] Nevertheless, because they are alternative measures of money, the Divisia and simple-sum aggregates are frequently compared to see how any analysis of the effects of monetary policy or other issues might be affected by the method of aggregation. The comparison of the levels of

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[11]The most widely used test, developed by Varian (1982, 1983), is not statistical. The null hypothesis of weak separability is rejected if a single violation of the so-called regularity conditions is found. Because tests for weak separability lack power, Barnett, Fisher and Serletis (1992, p. 2,095) argue that "existing methods of conducting such tests are not... very effective tools of analysis." See Barnett and Choi (1989) for evidence indicating that available tests of block-wise weak separability are not very dependable. For results of tests for weak separability, see Belongia and Chalfant (1989) and Swofford and Whitney (1986, 1987).

[12]A common practice both in the United States and abroad is to construct Divisia monetary aggregates for collections of assets that are reported by the country's central bank. For example, see Yue and Fluri (1991), Belongia and Chrystal (1991) and Ishida (1984).

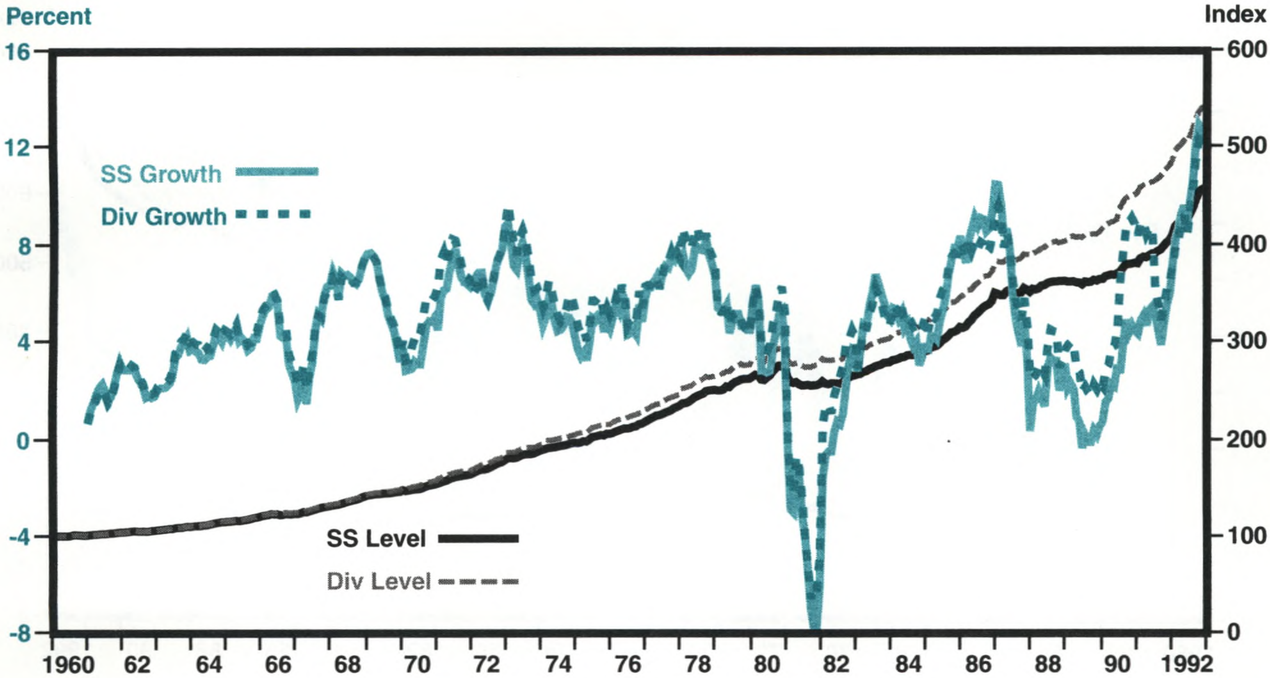
[13]It should be noted that the accounting stock, that is, the sum of the dollar amounts of all assets that are considered money, is not necessrily equal to the capital stock of money. The accounting stock is the present value of both service flow of money and the interest income (the service as a store of value). The economic capital stock of money comprises only the present value of the flow of monetary services. See Barnett (1991) for the formula for the economic capital stock of money.

[14]For the Divisia monetary aggregates, the share weight of each component's growth rate is its expenditure share of total expenditures on monetary services. Theoretically the share weights for the Divisia monetary aggregates are not a function of prices or user costs, but of quantities. The observable user costs are substituted for the unobservable marginal utilities under the implicit assumption of market-clearing equilibrium, where each consumer holds an optimal portfolio of monetary and nonmonetary assets. For the simple-sum monetary aggregates, the share weights are the components' share of the aggregate.

[15]$GDM_j = \ln DI_t - \ln DI_{t-1}$, where DI denotes the Divisia index. The index is initialized at 100, that is, $DI_0 = 100$. See Farr and Johnson (1985) for more details.

[16]Rotemberg (1991) derives a weighted monetary aggregate stock under conditions of risk neutrality and stationarity expectations; however, Barnett (1991) shows that this measure is the discounted value of future Divisia monetary service flows.

Figure 1
Year-Over-Year Growth of SSM1a and DIVM1a, and Levels of SSM1a and DIVM1a



the simple-sum and Divisia measures is made by normalizing both measures so that they equal 100 at some point in the series, usually the first observation.[17] Comparisons of the levels and growth rates of the Divisia and simple-sum measures are presented in figures 1–5 for four monetary aggregates, M1A, M1, M2 and M3, and for total liquid assets, L.[18] The figures have two scales. The left-hand scale indicates the growth rate, and the right-hand scale indicates the level of the series. Both indexes equal 100 in January 1960.

M1A

M1A comprises currency and non-interest-bearing demand deposits held by households and businesses. Although neither household nor business demand deposits earn explicit interest, business demand deposits are assumed to earn an implicit own rate of return proportional to the rate paid on one-month commercial paper.[19] Consequently, additional units of business demand deposits are assumed to yield a smaller

[17]An alternative justification for comparing the Divisia and simple-sum aggregates might come from noting that the appropriate Divisia monetary aggregate would be the simple-sum aggregate if all of the component assets had identical own rates. Such a comparison is tenuous, however, because the actual level of the simple-sum aggregate might have been different from the observed level had the user costs actually been equal.

It is common to compare the levels and growth rates of simple-sum and Divisia monetary aggregates. For example, see Barnett, Fisher and Serletis (1992). Because Divisia indexes involve logarithms, the growth rate of a component asset is plus or minus infinity, respectively, when a component is introduced or eliminated. To circumvent this problem, the Divisia index is replaced by Fisher's ideal index at these times and the user cost is measured by its reservation price during the period that precedes the introduction or follows the elimination of the asset. See Farr and Johnson (1985) for a discussion of this procedure.

[18]Note that the simple-sum aggregates presented here are not identical to the official published series. The official series are obtained by adding the non-seasonally adjusted components and seasonally adjusting the aggregate as a whole or by adding large subgroups of component assets that have been seasonally adjusted as a whole. The simple-sum aggregates presented here are obtained by adding the components after each component (that has a distinctive seasonal) has been seasonally adjusted. See the Appendix for details. A comparison of the series used here and the official series shows that the differences are small.

[19]Alternatively, estimates of the own rate on household demand deposits could also be used. However, such a series was not available for the entire sample period. Moreover, the desire was to follow the procedure used by Farr and Johnson (1985) as closely as possible.

Figure 2

Year-Over-Year Growth of SSM1 and DIVM1, and Levels of SSM1 and DIVM1

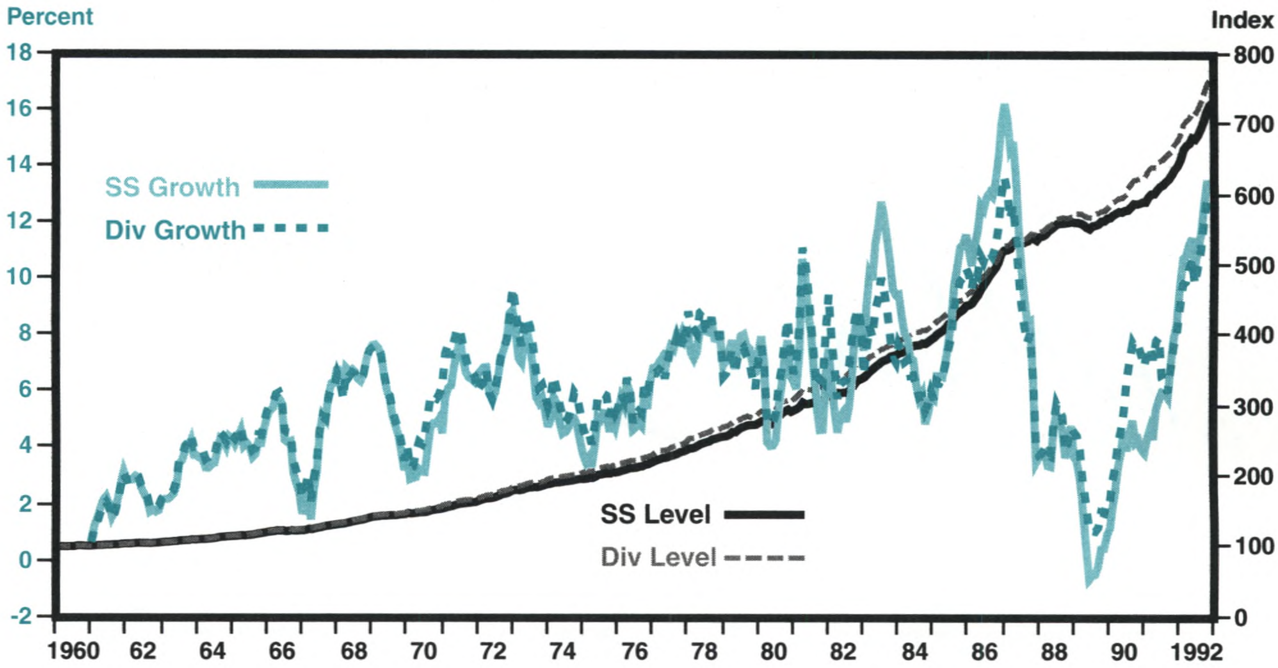


Figure 3

Year-Over-Year Growth of SSM2 and DIVM2, and Levels of SSM2 and DIVM2

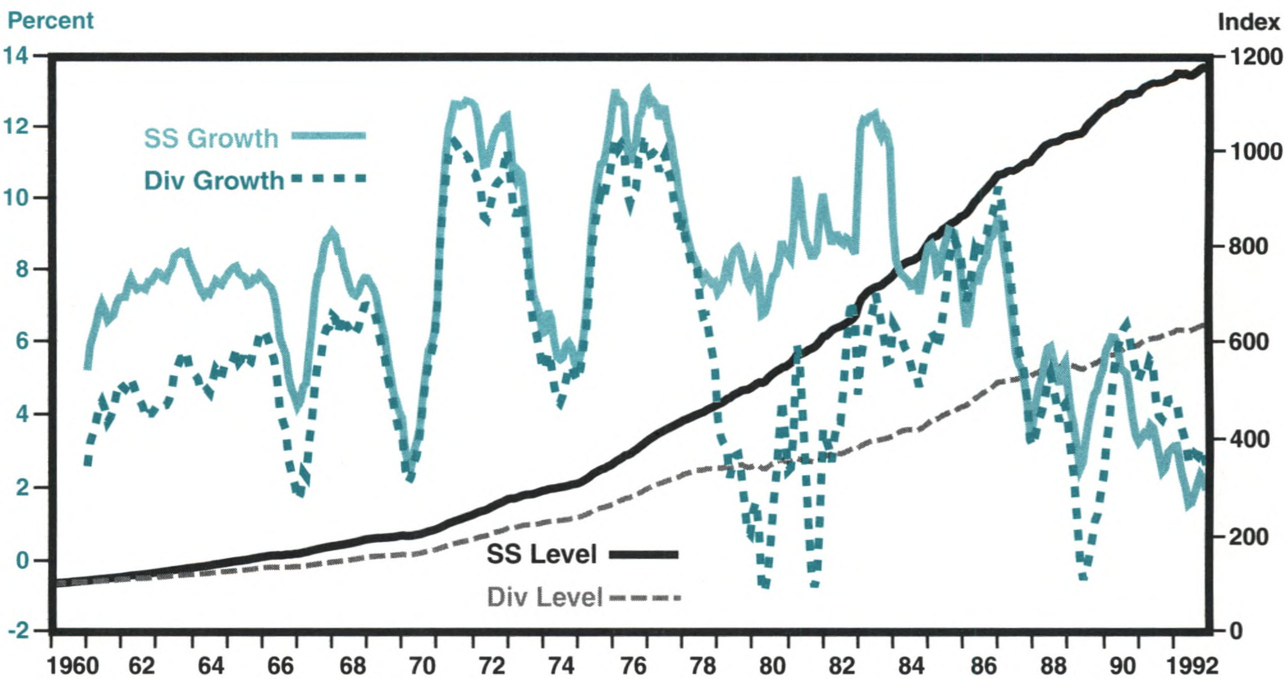


Figure 4
Year-Over-Year Growth of SSM3 and DIVM3, and Levels of SSM3 and DIVM3

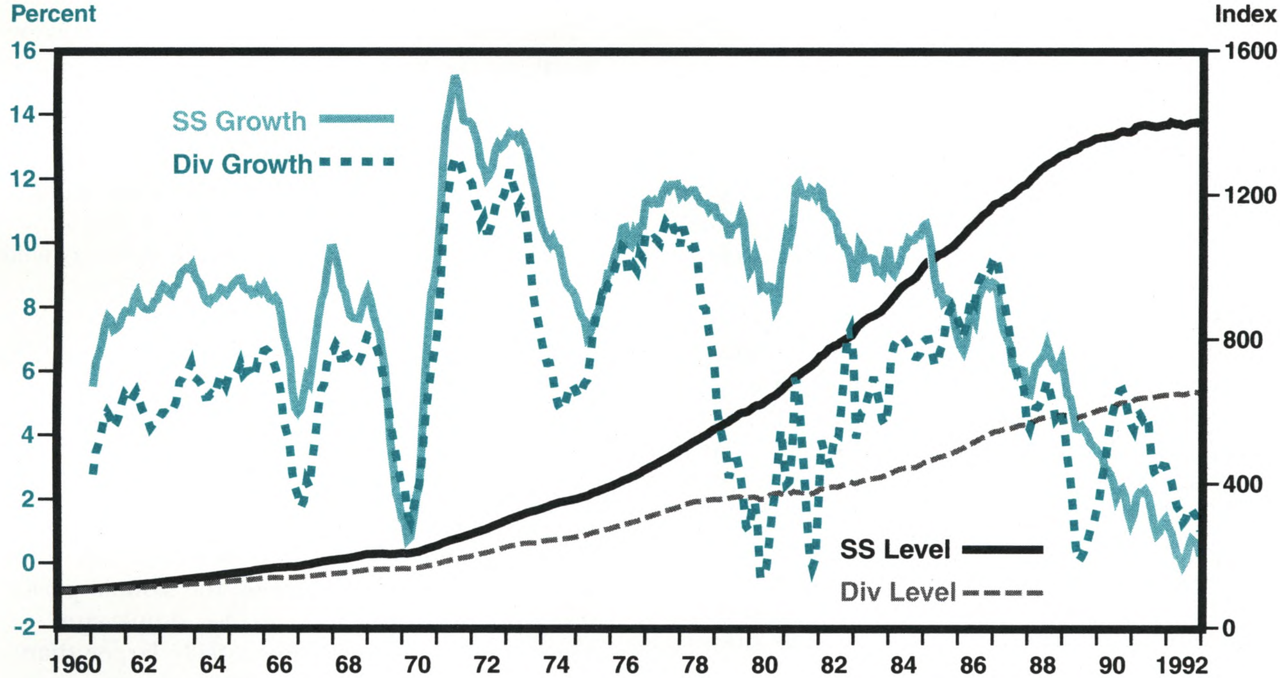
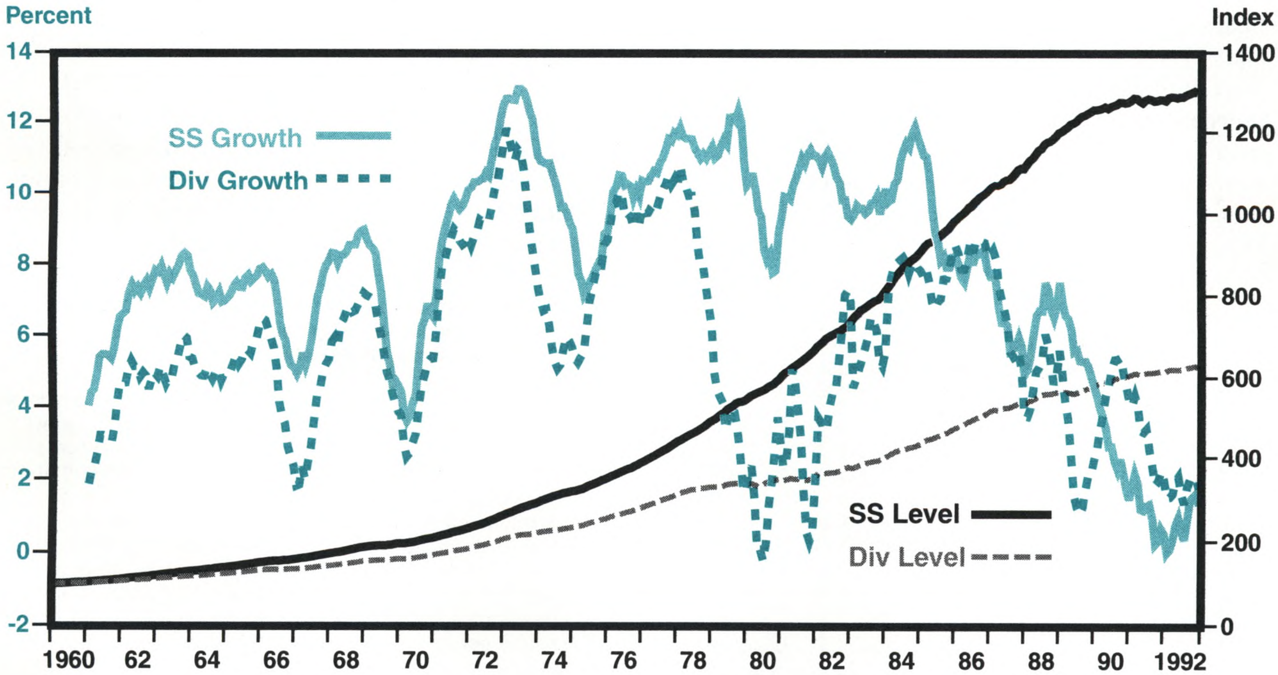


Figure 5
Year-Over-Year Growth of SSL and DIVL, and Levels of SSL and DIVL



flow of monetary services than are additional units of household demand deposits. On the other hand, the simple-sum measure implicitly assumes that each unit of each component provides the same flow of monetary services. Hence the Divisia aggregate gives more weight to the growth rates of currency and household demand deposits than does the simple-sum aggregate.[20]

The average differences in the growth rates of the simple-sum and Divisia measures of M1A for the entire sample period, January 1960 to December 1992, and for selected sub-periods are presented in table 1. Because currency generally grew more rapidly than demand deposits over the sample period, the growth rate of Divisia M1A averaged about half a percentage point higher than the growth rate of simple-sum M1A over the entire period.[21] Much of this difference occurs during the latter part of the 1980s, when the growth rate of demand deposits generally slowed relative to the growth rate of currency.[22] This more rapid growth of the Divisia measure is reflected in a generally widening gap between the levels of the indexes.

M1

The behavior of simple-sum and Divisia M1 is similar to that of M1A. Indeed, the growth rates of simple-sum and Divisia M1 were similar until the late 1970s, when the growth of interest-bearing NOW accounts began to accelerate. The sharp rise in NOW accounts after their nationwide introduction on January 1, 1981, tended to increase the growth rate of the simple-sum measure relative to the Divisia measure because the growth rate of NOW accounts gets a smaller weight in the Divisia measure. As a result, the Divisia measure grew more slowly on average than the simple-sum measure from the late 1970s until the mid-1980s, after growing more rapidly previously. However, in neither period is the average difference in the growth rate of the alternative measures large.[23]

After the late 1980s the Divisia measure grew more rapidly than the simple-sum measure, reflecting the rise in the growth rate of currency relative to the growth rate of checkable deposits. Of course, the smaller average difference in the growth rates of the alternative M1 aggregates compared with M1A is reflected in a smaller difference in the levels of the two indexes as well.

M2, M3 and L

Not surprisingly, larger differences arise when the monetary measures are broadened to include savings-type deposits because their explicit own rates of return are higher than those of transactions deposits. The higher own rate reduces the share weights of these component assets relative to the weights they receive in the simple-sum measures. During the sample period the growth rates of the broader simple-sum aggregates tend to be substantially larger than those of the corresponding Divisia measures. For the broader measures, the average growth rates of the simple-sum measures are about 2 percentage points greater than the corresponding Divisia measures over the entire sample period.

Much of this difference arises from the late 1970s to the mid-1980s and is likely due to financial innovation and deregulation in the period. The late 1970s witnessed a marked acceleration in the growth of money market mutual funds. These accounts paid relatively high interest rates and had limited transactions capabilities. A number of new deposit instruments that paid higher market interest rates were

[20]In both cases, the sum of the weights must equal unity.

[21]Currency grew at an annual rate of 7 percent during the entire period, whereas household and business demand deposits both grew at a 3.2 percent annual rate.

[22]This is a period of very slow reserve growth. Because reserves and checkable deposits are tied closely together under the present system of reserve requirements, it is not surprising that this is also a period of slow growth in checkable deposits, including household and business demand deposits. See Garfinkel and Thornton (1991) for a discussion of the relationship between reserves and checkable deposits under the present system of reserve requirements.

[23]We have refrained from using the phrase "statistically significant" because these observations are clearly distributed identically and independently, so the "t-statistics" reported in table 1 are biased and neither the direction nor extent of the bias is known. These statistics are presented to give the reader a rough approximation of the magnitude of the differences in the growth rates. Correlegrams of the difference in the growth rates of simple-sum and Divisia M1A and M1 show some lower level persistence through the sample period and some large spikes at seasonal frequencies after 1969. Correlegrams for the difference in the growth rates of the broader monetary aggregates reveal some higher level persistence. In any event, differences that are small in absolute value tend to be small relative to the estimated standard errors, and differences that are large in absolute value tend to be large in relative terms.

Another measure of the distance between the growth rates is the square root of the sum of the squared differences in the growth rates. These measures for the entire sample period are 58.5, 52.1, 69.6, 81.4 and 77.6 for M1A, M1, M2, M3 and L, respectively. These data are broadly comparable with those presented in table 1.

Table 1

Average Percentage Point Difference in the Annual Growth Rate of Simple-Sum and Divisia Aggregates

Period	Aggregate	Mean[1]	Standard Deviation	t-statistic
1960.01–1992.07				
	M1A	–0.514	3.16	3.24*
	M1	–0.153	2.83	1.07
	M2	1.889	3.49	10.75*
	M3	2.317	3.88	11.88*
	L	2.223	3.66	12.07*
1960.01–1977.12				
	M1A	–0.285	2.04	2.05*
	M1	–0.253	2.03	1.82
	M2	1.660	1.54	15.81*
	M3	2.134	2.08	15.02*
	L	1.897	1.73	16.10*
1978.01–1986.12				
	M1A	–0.324	3.83	0.88
	M1	0.420	3.65	1.20
	M2	3.526	5.59	6.55*
	M3	4.334	5.75	7.84*
	L	4.303	5.50	8.12*
1987.01–1992.12				
	M1A	–1.485	4.41	2.85*
	M1	–0.714	3.32	1.82
	M2	0.116	2.45	0.40
	M3	–0.163	2.82	0.49
	L	0.076	2.84	0.23

[1]The growth rate of the simple-sum aggregate less the growth rate of the Divisia aggregate.

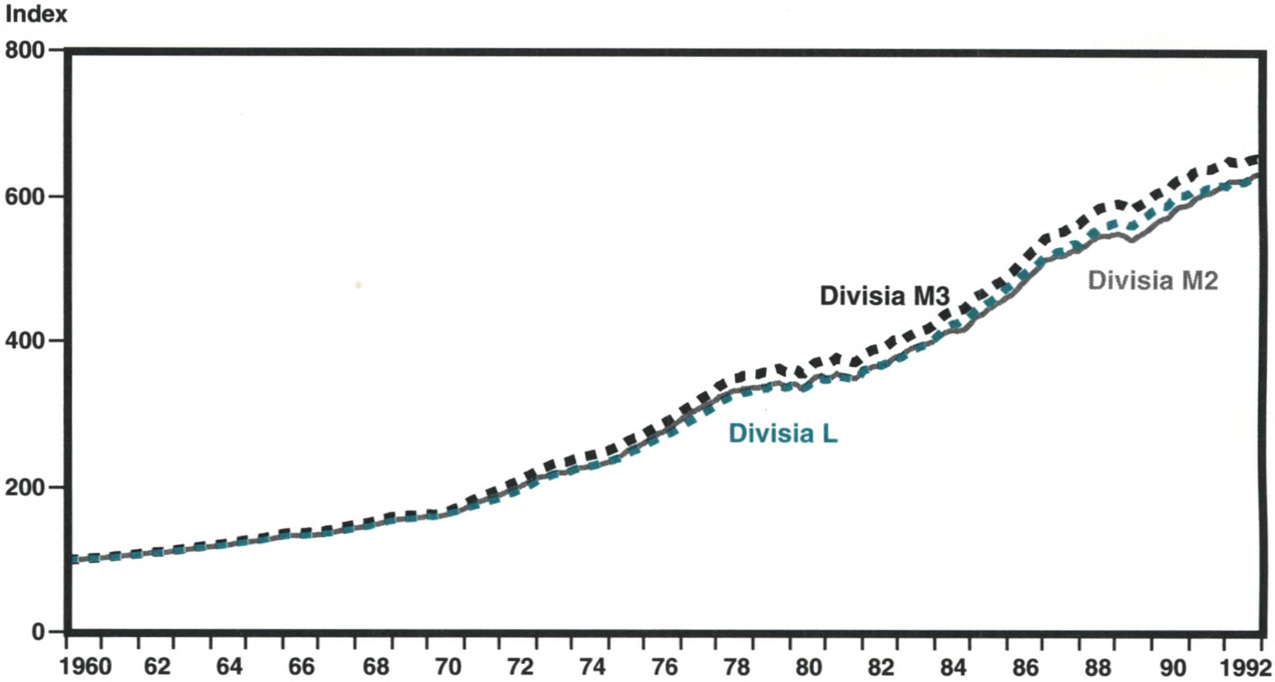
*Indicates a t-statistic greater than 2. See footnote 23.

introduced in the early 1980s and Regulation Q interest rate ceilings were being phased out.[24] Moreover, short-term interest rates reached very high levels in the early 1980s. With share weights sensitive to the spread between an asset's own rate of return and the return on the benchmark asset, it is not surprising that the Divisia measures grew markedly slower than the corresponding simple-sum measures during this period. Nevertheless, the significantly slower growth of the broader Divisia measures during this period is more consistent with the disinflation of the period than is the growth of the simple-sum aggregates, whose growth remained fairly rapid. Although the growth rates of the broader Divisia and simple-sum aggregates have been essentially the same, on average, since about the mid-1980s, the pattern of growth of these alternative measures is somewhat different.

[24]For a discussion of the financial innovations of this period see Gilbert (1986) and Stone and Thornton (1991).

Figure 6

Levels of Divisia M2, M3, and L



A Comparison of Broader Divisia Aggregates

That Divisia aggregation gives relatively small weight to less liquid assets that yield high rates of return suggests that differences in the growth rates of successively broader Divisia monetary aggregates will tend to get smaller.[25] The levels of Divisia M2, M3 and L presented in figure 6 and simple correlations of the compounded annual growth rates of these Divisia aggregates presented in table 2 confirm this. The growth rates of Divisia M3 and L differ little from the growth rate of Divisia M2. This implies that adding successively less liquid assets to those in M2 adds little to the flow of monetary services.[26] That the average difference in the growth rates of Divisia M2 and L is nearly zero over the entire sample period is reflected by the levels of the two Divisia aggregates, which are essentially equal by the end of the sample. Divisia M3, however, has grown more rapidly than the other measures, so the spread between its level and the levels of Divisia M2 and L has widened over the sample period.

CONCLUDING REMARKS

Despite their theoretical advantage, Divisia and other weighted monetary aggregates have garnered relatively little attention outside of academe, and the official U.S. monetary aggregates remain simple-sum aggregates. The official reliance on simple-sum aggregates will probably continue unless the Divisia aggregates or other alternative weighted aggregates are shown to be superior in economic and policy analysis.

[25] Of course this tendency also exists for the simple-sum aggregates. For the simple-sum aggregate, the growth rate of each component is weighted by the component's share of the total asset. Hence the growth rates of successively broader monetary aggregates could diverge if the marginal components were successively larger. For example, this is what happens from M1 to M2. The growth rates tend to converge, however, because the marginal components are smaller. This tendency is exacerbated in the Divisia measures because of smaller weights associated with higher own rates of return on successively less liquid assets.

[26] The average differences in the growth rates of Divisia M2, M3 and L over the sample period are small (less than 0.12 percentage points in absolute value). The absolute values of the average differences in the growth rates of simple-sum M2, M3 and L are larger than those of the corresponding Divisia measures; the standard errors are also much larger.

Table 2

Correlations of the Annual Growth Rates of the Divisia Monetary Aggregates

Aggregate	M1A	M1	M2	M3
M1	.7920			
M2	.6540	.6914		
M3	.6015	.6346	.9568	
L	.5754	.6126	.8863	.9216

Although nothing definitive can be said about this issue from the simple analysis of the data presented here, a few observations are offered.

First, that the growth rates of the narrow simple-sum and Divisia monetary aggregates are quite similar suggests that the method of aggregation may not be important at low levels of aggregation.[27] For example, it does not appear that conclusions about the long-run effects of money growth on inflation would be much different using either simple-sum or Divisia M1 or M1A. The average difference in the growth rates of narrow simple-sum and Divisia monetary aggregates is small. This observation is consistent with the empirical work of Barnett, Offenbacher and Spindt (1984) who, using a broad array of criteria, found that the difference in the performance of simple-sum and Divisia monetary aggregates was small at low levels of aggregation.

Second, the method of aggregation is likely to be more important for broader monetary aggregates. Beyond some point, however, a further broadening of the monetary aggregate makes little difference. For the United States, the differences in the average growth rates of Divisia M2, M3 and L are small. Consequently, long-run analysis using the growth rates of any of these Divisia aggregates is likely to produce similar results. Monthly growth rates of these Divisia aggregates are also highly correlated. Hence it would not be too surprising to find that the broader Divisia aggregates perform similarly to one another in many short-run analyses as well.

These observations point to the critical need for more work to determine which financial assets should be included in the appropriate monetary aggregate. In consumer demand theory, these assets must satisfy the condition of weak separability. If analysis suggests a relatively narrow monetary aggregate such as M1, policymakers may be reluctant to adopt the theoretically superior index measure because, as a practical matter, the method of aggregation may not be empirically important.

If such tests point to an aggregate that includes a much broader array of financial assets, the practical case for the weighted aggregates will be enhanced. Even casual analysis of simple-sum and Divisia monetary aggregate data show differences in both the levels and growth rates of these aggregates that are large, suggesting that the method of aggregation is important. Consequently, the method of aggregation should also be a concern for those who favor broader monetary aggregates on other grounds. The objective of the present article in publishing Divisia monetary statistics is to stimulate further empirical research both on the importance of monetary aggregation and on the role of money in the economy.

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Appendix
Constructing Divisia Monetary Aggregates: 1960-1992[1]

The assets used to calculate Divisia monetary aggregates are the same as those used by the Board of Governors to calculate the official simple-sum aggregates M1A through L. The only major difference is that demand deposits are broken into household demand deposits (HDD) and business demand deposits (BDD). We assume that households receive a zero rate of return on demand deposits and that businesses receive an implicit, nonzero rate of return. HDD and BDD are computed using seasonally adjusted monthly data for total demand deposits and non-seasonally adjusted quarterly data for consumer, foreign, financial, nonfinancial and other demand deposits. These can be found in Table 1.31 of the *Federal Reserve Bulletin*. Using the non-seasonally adjusted quarterly data, we calculate two ratios and use them to partition the seasonally adjusted monthly data. The ratio for BDD is the sum of financial and nonfinancial demand deposits divided by the sum of all five non-seasonally adjusted series, whereas the ratio for HDD is one minus the BDD ratio. The non-seasonally adjusted series go back only to 1970.01 and are discontinued after 1990.06. For data before 1970.01 and after 1990.06, the means of the respective ratio series over the available sample were used. The means used were 62.33 percent for BDD and 37.67 percent for HDD. To get the final HDD and BDD series, these quarterly ratios were multiplied by the seasonally adjusted monthly data for total demand deposits. Each quarterly observation was multiplied by the three months of data for that particular quarter. All assets are seasonally adjusted and in millions of dollars.

[1]The Divisia monetary aggregates data presented here were constructed under the direction of Piyu Yue. Lynn D. Dietrich and Kevin L. Kliesen gathered the data, wrote the computer code and wrote this appendix.

Money Components

CUR — Sum of seasonally adjusted currency and traveler's checks.

DEMDPS — Total demand deposits.

HDD — Demand deposits for households as described in the preceding section.

BDD — Demand deposits for businesses as described in the preceding section.

OCD — Other checkable deposits less super NOW account balances. OCD includes ATS and NOW balances, credit union share draft balances and demand deposits at thrift institutions.

SNOWC — Super NOW accounts at commercial banks. SNOWC data begin in 1983.01 and end in 1986.03. After 1986.03 there is no distinction between NOWs and super NOWs.

SNOWT — Super NOW accounts at thrifts. SNOWT begin in 1983.01 and end in 1986.03. After 1986.03 there is no distinction between NOWs and super NOWs.

ONRP — Overnight repurchase agreements. ONRP includes overnight and continuing contract repurchase agreements issued by commercial banks to organizations other than depository institutions and money market mutual funds (MMMFs) (general purpose and broker/dealer organizations).

ONED — Overnight eurodollars. ONEDs are issued by foreign (principally Caribbean and London) branches of U.S. banks to U.S. residents and organizations other than depository institutions and money market mutual funds.

MMMF — Money market mutual funds. MMMF is general purpose and broker/dealer money market mutual fund balances including taxable and tax-exempt funds and excluding IRA/KEOGH accounts at money funds.

MMDAC — Money market deposit accounts at commercial banks. MMDAC initially had a minimum balance requirement of $2,500 until December 31, 1984, and a $1,000 minimum balance requirement until December 31, 1985, when the requirement was removed. MMDACs were no longer reported after 1991.08.

MMDAT — Money market deposit accounts at thrifts. MMDAT initially had a minimum balance requirement of $2,500 until December 31, 1984, and a $1,000 minimum balance requirement until December 31, 1985, when the minimum requirement was removed. MMDATs were no longer reported after 1991.08.

SDCB — Savings deposits at commercial banks less money market deposit accounts at commercial banks. MMDACs are included after 1991.08.

SDSL — Savings deposits at thrifts less money market deposit accounts at thrifts. MMDATs are included after 1991.08.

STDCB — Small time deposits (less than $100,000) at thrifts including retail repurchase agreements less IRA/KEOGH accounts.

STDTH — Small time deposits (less than $100,000) at thrifts including retail repurchase agreements less IRA/KEOGH accounts.

LTDCB — Large time deposits (more than $100,000) at commercial banks excluding international banking facilities (IBFs).

LTDTH — Large time deposits (more than $100,000) at thrifts excluding IBFS.

MMMFI — Institution only money market mutual funds. MMMFI includes taxable and tax-exempt funds and excludes IRA/KEOGH accounts at money funds.

TRP — Term repurchase agreements. TRP consists of RPs with original maturities greater than one day, excluding continuing contracts and retail RPs.

TED — Term eurodollars with original maturities greater than one day. TED includes those eurodollars issued to U.S. residents by foreign branches of U.S. banks and by all banking offices in the United Kingdom and Canada. Eurodollars held by depository institutions and MMMFs are not included.

SB — Savings bonds.

STTS — Short-term Treasury securities. STTS comprises U.S. Treasury bills and coupons with remaining maturities of less than 12 months not held by depository institutions, Federal Reserve Banks, MMMFs or foreign entities.

BA — Bankers acceptances. BA is the net of bankers acceptances held by accepting banks, Federal Reserve Banks, foreign official institutions, federal home loan banks and MMMFs.

CP — Total commercial paper less commercial paper held by MMMFs.

The interest rate data are more complicated than the asset data. The major concern with the interest rate data is the variety of forms in which they are reported. Before including different rates in an aggregate, the characteristics of all the rates should be as similar as possible. To this end, two problems need to be addressed. First, for composite asset stocks where the total asset is the sum of deposits with different maturities, such as small and large time deposits, the own rate is the maximum rate paid across the deposit categories at each point.

Because there are a variety of maturity lengths among the rates of a given composite asset stock, an adjustment is needed to transform each rate to a common maturity before the final rate is computed. Given rates with differing maturities and a typical upward-sloping yield curve, liquidity premiums keep rates on assets with longer maturities higher than rates on those with shorter maturities. To adjust these rates to a common maturity, this liquidity premium must be removed using a yield curve adjustment as described in Farr and Johnson (1985). As Farr and Johnson did, all rates that are yield curve adjusted are adjusted to a one-month maturity:

$R^* = R - (TB_M - TB_1)$, where

R = the original rate on a bond basis (that is, a 365-day basis) basis

R^* = the yield curve adjusted rate

TB_M = the M-month Treasury bill rate

TB_1 = the one-month Treasury bill rate

A second adjustment is needed to convert all the rates to the same yield basis. Interest rates are quoted in various forms, including discount basis and annual percentage rate basis, and have various interest bases, including bond (365 day) and bank (360 day). To the extent possible, the rates were transformed into annualized one-month investment yields on a bond-interest basis. For rates quoted on a discount basis for a 360-day year, the following formula can be used to convert them to an annualized yield for a 365-day year (see Farr and Johnson [1985]):

$$R = \left([(365*D)/100] \;/\; \{360-[(N*D)/100]\}\right) * 100,$$

where R = the annualized rate
D = a discount basis rate (360-day year)
N = the number of days to maturity

Including the variable N ensures that the formula is maturity independent.

Interest Rate Series for the Monetary Components

RZER — Rate on currency and traveler's checks. RZER is zero by definition.

RDD1 — Rate on household demand deposits. RDD1 is zero by definition.

RDD2 — Rate on business demand deposits. The basic formula for computing is as follows:

$$RDD2 = (1\text{-}MRR)*RCP$$

where MRR = maximum reserve requirement on demand deposits
RCP = one-month financial paper rate

Before applying this formula, adjust RCP, which is quoted on a discount basis for a 360-day year, to an annualized one-month yield for a 365-day year. This is done by using the formula described in the preceding text.

$RCP^* = ([(365*RCP)/100]/\{360-[(30*RCP)/100]\})*100$

Then $RDD2 = (1-MRR)*RCP^*$

For MRR and all ceiling rates used in the following text, we use the same convention as Farr and Johnson and assume that rates are quoted as annualized one-month yields.

ROCD — Rate on other checkable deposits.

1960.01–1974.11 — Regulation Q ceiling rate on passbook savings accounts at commercial banks. From 1962.01–1964.12 the ceiling rate on savings deposits of less than 12 months is used.

1974.12–1986.03 — Regulation Q ceiling rate on NOW accounts.

1986.04–present — Weighted average interest rate on NOWs and super NOWs.

RSNOWC — Rate on super NOWs at commercial banks. RSNOWC is the average rate paid on super NOW accounts at insured commercial banks and is quoted on an effective annual yield in the monthly Survey of Selected Deposits, a special supplementary table in the weekly *Federal Reserve Statistical Release* H.6.

RSNOWT — Rate on super NOWs at thrift institutions. RSNOWT is the average rate paid on super NOW accounts at FDIC-insured savings banks (both mutual and federal savings banks) and is quoted on an effective annual yield in the monthly Survey of Selected Deposits, a special supplementary table in the weekly *Federal Reserve Statistical Release* H.6.

RONRP — Rate on overnight dealer financing in the repurchase market. Because RONRP is an overnight rate quoted on a bank-interest basis, it must be transformed into an annualized one-month yield on a bond-interest basis using the following formula:

$RONRP^* = \{[1+(RONRP/36000)]^{30}-1\}*(36500/30)$

Data for RONRP goes back only to 1972.01, whereas asset data goes back to 1969.11. Farr and Johnson argue that the rate on overnight RPs has historically been five basis points below the federal funds rate, so we use the following formula to compute a rate before 1972:

$RONRP^* = (\{[1+(RFF/36000)]^{30}-1\}*(36500/30)) -.05$

Like RONRP, the fed funds rate is an overnight rate quoted on a discount basis and must be transformed into an annualized one-month yield on a bond-interest basis.

RONED — Rate on overnight eurodollars from London. The original series is weekly, and thus the monthly series is a simple average of the weekly observations for a particular month. Like RONRP, RONED is an overnight rate quoted on a bank-interest basis and must be converted to an annualized one-month yield on a bond-interest basis using the following formula:

$RONED^* = \{[1 + (RONED/36000)]^{30}-1\}*(36500/30)$

RMMMF — Average yield of money market mutual funds. RMMMF comes from the Board, which in turn gets it from *Donoghue's Money Fund Report*. Data for RMMMF is available only back to 1974.06. RMMMF data from before this date are set to the rate on large time deposits at commercial banks (RLTDCB) less 70 basis points (see Farr and Johnson [1985]).

RMMDAC — Rate on money market deposit accounts at commercial banks. Before 1989.06 RMMDAC is the average rate paid at insured commercial banks. After 1989.07 it is the average of the rates paid at insured commercial banks for personal and nonpersonal MMDAs, which are quoted as effective annual yields in the monthly Survey of Selected Deposits, a special supplementary table in the weekly *Federal Reserve Statistical Release* H.6.

RMMDAT — Rate on money market deposit accounts at thrift institutions. Before 1989.06 RMMDAT is the average rate paid at FDIC-insured savings banks. After 1989.07 it is the average of the rates paid at FDIC-insured savings banks (including both mutual and federal savings banks) for personal and nonpersonal MMDAs, which are quoted as effective annual yields in the monthly Survey of Selected Deposits, a special supplementary table in the weekly *Federal Reserve Statistical Release* H.6.

RSDCB — Rate on savings deposits at commercial banks less money market deposit accounts at commercial banks. RSDCB comes from the Board and is quoted as an effective annual yield.

RSDSL — Rate on savings deposits at FDIC-insured savings banks (the thrift rate).

1966.10–1986.03 — The ceiling rate on NOW accounts at thrifts.

1986.04–present — The rate on savings deposits at thrifts published in the Board's H.6 release.

There are two problems with data before 1966.10: 1) interest rates on savings deposits at thrifts were not regulated and 2) different states paid different rates on these accounts. One of the few series published for this period is the average dividend paid on savings deposits at thrifts, which is what we use here. This is an annual rate and includes passbook savings accounts and fixed-term certificates.

FITSTCB — Rate on small time deposits and retail repurchase agreements at commercial banks. FITSTCB is the Fitzgerald-adjusted small time deposit rate that is calculated at the Board and quoted as an effective annual yield.

RSTTH — Rate on small time deposits and retail repurchase agreements at thrifts. RSTTH is the Fitzgerald-adjusted small time rate that is calculated at the Board and quoted as an effective annual yield.

RLTDCB — Rate on large time deposits at commercial banks. RLTDCB is a yield-curve-adjusted rate that is calculated using the one-, three- and six-month secondary CD rates (of deposits greater than $100,000) and the one-, three- and six-month Treasury bill rates.

1) The first step is to convert the Treasury bill rates, which are quoted on a discount basis for a 360-day year, to annualized yields for a 365-day year as follows:

$$Y* = \left([(365*Y)/100]/\{360-[(N*Y)/100]\}\right)*100$$

where Y = one-, three- and six-month Treasury bill rates on a discount basis
N = number of days to maturity

2) Second, calculate the yield-curve-adjusted three- and six-month CD rates using the following formula:

$$RCD3YCA = RCD3 - (Y3-Y1)$$
$$RCD6YCA = RCD6 - (Y6-Y1)$$

where RCD3 = three-month CD rate
RCD6 = six-month CD rate
Y1 = one-month Treasury bill rate
Y3 = three-month Treasury bill rate

3) Finally, the interest rate for large time deposits at commercial banks is given as follows:

RLTDCB — MAX (RCD1, RCD3YCA, RCD6YCA).

1) Data on CD rates were not available before 1964.06 so RLTDCB was set to the ceiling rate on savings deposits of less than one year as set by Regulation Q.

2) Before entering any calculations, the CD rates were multiplied by (365/360) to convert them to a bond, or 365-day, basis.

RLTDTH — Rate on large time deposits at thrifts. RLTDTH is simply the rate on large time deposits at commercial banks (RLTDCB) plus 30 basis points based on Farr and Johnson's result that the rate on large time deposits at thrifts has been about 30 basis points above that on large time deposits at commercial banks.

RMMMFI — Rate on institution-only mutual fund shares. RMMMFI is simply the rate on general purpose and dealer/broker mutual fund shares (RMMMF).

RTRP — Rate on term repurchase agreements. RTRP is equal to the rate on overnight RPs plus the difference of the rates on term eurodollars and overnight eurodollars (RONRP + [RTED-RONED]). Asset data for term RPs is available back to 1969.10, whereas data for RONED is available only back to 1971.01. From 1969.10 to 1970.12 the spread (RTED-RONED) is estimated as the average difference between the two rates for 1971.

RTED — Rate on term eurodollars. RTED is a yield-curve-adjusted rate computed from the one,- three- and six-month term eurodollar rates. It is calculated in the same way as the rate on large time deposits (RLTDCB).

1) First, use annualized rates on one-, three- and six-month Treasury bill rates to calculate the yield-curve-adjusted three- and six-month term eurodollar rates (see the formulas from RLTDCB).

2) The RTED rate will then be the maximum of the one-month term eurodollar rate and the three- and six-month yield-curve-adjusted term eurodollar rates.

NOTES:

1) Only data for the three-month eurodollar rate is available back to 1960.01, so RTED is just equal to that yield-curve-adjusted rate until 1963.05.

2) Before entering any calculations, the eurodollar rates were first multiplied by (365/360) to convert them to a bond-interest, or 365-day, basis.

RSB — Rate on savings bonds. RSB is a six-month average rate for the current month converted to a bond-interest basis by multiplying by (365/360).

RSTTS — Rate on short-term Treasury securities. RSTTS is simply the rate on the one-month Treasury bill. Data for the one-month Treasury bill rate is available only back to 1968.01, so data before 1968.01 is set at the three-month rate less the average difference between the one- and three-month rates for 1968.01 to 1990.12. Because this rate is quoted as a discount rate for a 360-day year, it is converted to an annualized one-month yield using the following formula:

$$RSTTS = \left([(365*TB1)/100]/\{360 - [(30*TB1)/100]\}\right)*100$$

RBA — Three-month bankers acceptances rate. Although this rate has a three-month maturity, it is not yield curve adjusted as RLTDCB and RTED were because only one rate is used in the calculation (compared with three used for each of the others). Instead, it is converted from a discount basis for a 360-day year to an annualized yield for a 365-day year using the following formula (see Farr and Johnson [1985]):

$$RBA^{*} = \left([(365*RBA)/100]/\{360 - [(90*RBA)/100]\}\right)*100$$

RCPL — Rate on commercial paper. RCPL is the rate on one-month financial paper, which is converted from a discount rate for a 360-day year to an annualized one-month yield for a 365-day year using the following formula:

$$RCPL^{*} = \left([(365*RCPL)/100]/\{360 - [(30*RCPL)/100]\}\right)*100$$

RBAA — Rate on Moody's Baa corporate bonds. RBAA is taken directly from the Board's G.13 release and is used only in the computation of the benchmark interest rate. It was yield-curve adjusted to a one-month annualized yield on a bond basis.

BENCH — BENCH is the highest yielding rate for the period among all 24 interest rate series and the Baa bond rate; that is,

$$BENCH = MAX\ [RBAA, (R_{it}, i = 1, \ldots, 24)].$$

Simple-sum and Divisia monetary aggregates presented in this article can be downloaded from the FRED electronic bulletin board with a personal computer and a modem. The monetary aggregates are in a file called "DIVISIA." To access FRED, dial 314-621-1824. Parameters for communication software should be set to no parity, word length = 8 bits, one stop bit, full duplex and the fastest baud rate your modem supports, up to 9,600 bps. For more information, telephone Tom Pollmann at 314-444-8562.

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