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Familiar Developments in Bank Loan Markets

*By John H. Wood**

Of the many recent changes in bank loan markets, perhaps the most dramatic have been the strong tendencies toward shorter loan maturities and more volatile loan rates—this volatility increasing both absolutely and relative to other short-term interest rates. These changes have been the principal means by which banks have sought to hedge interest rate risk in the face of increasing variations in their costs of funds. The main theme of the present article is that these developments represent in their most significant aspects a return to the conditions and practices that characterized bank loan markets before 1930. Hence the title "Familiar Developments. . . "

A supporting theme contends that the differences in bank loan practices between three more or less distinct periods (before 1930, the mid-1930's to the mid-1960's, and the late 1960's to the present) may be explained by differences in the volatility of interest rates between those periods. An average short-term business loan rate and the 4- to 6-month prime commercial paper rate during 1919–83 are shown in Chart 1. Notice the low and (more important for our purposes) relatively steady rates during the middle period extending from the mid-1930's to the mid-1960's, between two periods of higher and more volatile rates, although "mid-1960's" might easily be replaced by either "late 1950's" or "early 1970's," depending on one's idea of volatility. This article is not concerned with the causes of interest rate volatility. The patterns in Chart 1 are taken as given and the discussion will focus on the responses of banks and their customers to those patterns.

The following sections begin with a description of financial markets during the half century preceding 1930, with the purpose of demonstrating that bank incentives and capabilities were much like those of today. The next section describes bank loan portfolios during the 1920's. The pre-1930 period is then contrasted with the marked changes in bank loan markets that resulted first from the Great Depression and bank panics of 1929–33 and then from the prolonged period of low and stable interest rates and generally easy money of 1933–52—the most

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notable of these changes being the growing importance of long-term loans and the greater stability of loan rates, even in relation to other interest rates. The next-to-last section describes the recent return of bank lending practices to those of the 1920's and attributes this reversion of behavior to the return of the pre-1930 environment of volatile interest rates and bank reserves. The last section contains a brief summary.

Financial markets before 1930 (and after 1960)

The present American financial system was essentially in place by 1880. All but a few of the financial instruments, institutions, and trading procedures that exist today were familiar then. Institutional developments during the preceding 90 years included the organization of the New York Stock Exchange in 1792,[1] establishment of the New York Clearing House in 1853, the rapid growth of commercial banks, private investment banking houses, insurance companies, and savings societies, especially following the Civil War, the rapid spread of the commercial paper market after the 1840's, and the adoption of standardized futures contracts by the Chicago Board of Trade in 1865. The most dramatic technical developments were the invention of the telegraph in 1844 and its almost completed nationwide network by 1861, laying of the Atlantic cable in 1866, establishment of the stock ticker in 1867, and the invention and quick success of the telephone in the late 1870's. Institutional and technological developments affecting the financial markets since that time have consisted largely of attempts to keep pace with the nation's business.

Focusing on banks, nearly all of the significant peculiarities of the American banking system were developed last century, although some of the names have changed. The great contribution of a well-developed financial system is the efficient transfer of funds from savers to investors. Commercial banks are essential to this process in the first instance because of their role as managers of the payments system. Borrowers and lenders, whether trading directly or through financial intermediaries, exchange funds by exchanging claims on banks. Banks also perform the intermediary function of borrowing from savers in order to lend to investors. The efficient performance of these functions is particularly challenging in the United States because of the size and diversity of the country. Possibly the most efficient means of transferring funds between regions, and that used in most countries, is a system of national banks. But Americans, who may be most in need of such a system, have by severe legal restrictions on branch banking, especially the prohibition of interstate branching, denied themselves the benefits of national banks.[2] Banks in surplus, low-interest-rate regions have not had branches in deficit, high-interest-rate regions to which to transfer funds.

But where there's a dollar there's a way. The 19th century saw the evolution of a competitive national banking system in spite of regulation.[3] The system was based on correspondent banking and bankers' balances. Then as now, correspondent banks in New York, Chicago, San Francisco, and other financial centers managed the reserves and money market investments, cleared the checks, and performed other services for banks in smaller cities and rural areas. Bankers' balances, largely demand deposits held with their urban correspondents by smaller banks in outlying areas, were the principal form of interbank lending. Until interest on demand deposits was made illegal by the Glass-Steagall Banking Act of 1933, large banks competed for the balances of small banks by paying interest. Contemporary accounts were replete with condemnations by politicians and others of the "vicious" practice of enticing funds from productive local uses to the "maelstrom of stock gambling" in New York by pay-

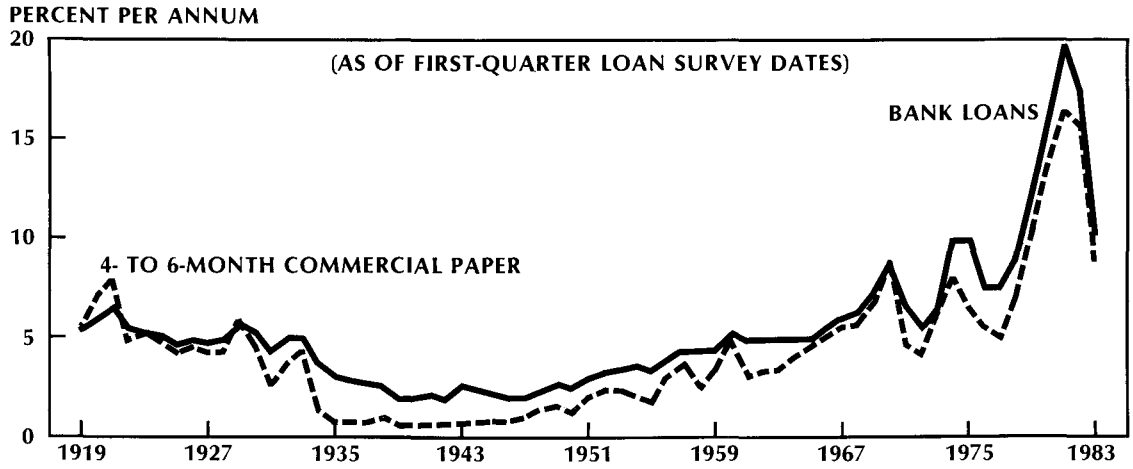
1. The structure and trading procedures of the New York Stock Exchange have changed little since the continuous auction and specialist systems were introduced in the 1870's.

2. A charter conferred by the Comptroller of the Currency under the National Banking Act of 1863 makes a bank "national" only in name.

3. The success of this system in achieving sympathetic movements in bank loan rates throughout the country has been documented by Lance E. Davis, "The Investment Market, 1870-1914: The Evolution of a National Market," *Journal of Economic History* 25 (September 1965): 355-99; Robert E. Keleher, "Regional Credit Market Integration: A Survey and Empirical Examination," Federal Reserve Bank of Atlanta, Working Paper Series (Atlanta, 1979); and Dale K. Osborne, "Is the Southwest Short of Capital?" *Economic Review*, Federal Reserve Bank of Dallas, January 1983, 1-10.

Chart 1

Interest Rates on Short-Term Bank Loans and Commercial Paper



SOURCE: Board of Governors, Federal Reserve System (*Banking and Monetary Statistics, 1914–1941* and *1941–1970; Annual Statistical Digests;* and *Federal Reserve Bulletins*).

ing interest on deposits.[4] Bankers deplored this practice as much as anyone and attempted to "regulate competition" by agreements on uniform rates of interest—usually zero for demand deposits. But these price-fixing arrangements failed because of "the ignorance, selfishness, or immoral conduct" of a few banks in each locality.[5] A dozen of 60 members of the New York Clearing House paid interest on deposits in 1857, a practice continued by about half a dozen of 38 national banks in that city in 1907.[6] These banks and their competitors in other cities held the bulk of interbank deposits and thus as a group held the country's reserve and served as the principal conduits through which funds flowed between and within regions.

These aggressive banks, heavily dependent on managed, interest-bearing liabilities, found another source of funds in clearinghouse balances. Some clearinghouses had arrangements by which banks

4. The quoted words were used by Carter Glass in defense of the prohibition of interest on demand deposits. See "Legislative History of Provision of Banking Act of 1933 Prohibiting Payment of Interest by Banks on Demand Deposits," in U.S. Congress, House Committee on Banking and Currency, *To Eliminate Unsound Competition for Savings and Time Deposits: Hearings on H.R. 14026, A Bill to Prohibit Insured Banks from Issuing Negotiable Interest-Bearing or Discounted Notes, Certificates of Deposit, or Other Evidences of Indebtedness*, 89th Cong., 2d sess., 1966, 651–53. For several 19th-century expressions of this view, see O. M. W. Sprague, *History of Crises Under the National Banking System*, in *National Banking System*, vol. 5 of Publications of National Monetary Commission, 61st Cong., 2d sess., 1910, S. Doc. 538, 321–86.

5. From an address by George S. Coe, president of the American Exchange National Bank, in presenting a resolution to the New York Clearing House Association on June 4, 1884, "to make common cause" by inquiring "whether the methods of business, as conducted by the several members of this association, are uniform and correct in their operation with the public, and equitable to all the banks which are thus bound together in the Clearing House Association" (Published in *Bankers' Magazine*, July 1884, 44–51, and reprinted in Sprague, *History of Crises*, 371–80). For descriptions of attempts to fix deposit rates in other cities, see James G. Cannon, "Clearing Houses and the Currency," in *The Currency Problem and the Present Financial Situation* (New York: Columbia University Press, 1908), 99; and Walter E. Spahr, *The Clearing and Collection of Checks* (New York: Bankers Publishing Co., 1926). For an account of the Federal Reserve System's encouragement of those attempts, see *Federal Reserve Bulletin* 6 (February 1920): 157.

6. Sprague, *History of Crises*, 20, 232.

that were indebted to the clearinghouse in the morning in amounts too large to settle immediately without inconvenience, but with expected inflows of funds (usually by calling loans) in the afternoon, could borrow from other banks. About 60 percent of claims at the Boston Clearing House were settled this way in 1900. "In practice, some banks habitually loan, but never borrow. Others habitually borrow, but seldom or never loan. . . . The rate of interest on such loans corresponds very closely with the rate on call loans."[7]

The practice of borrowing and lending clearinghouse balances was extended to deposits with Federal Reserve Banks and called "federal funds" in the 1920's. Most fed funds transactions were handled by securities dealers that also dealt in government securities, commercial paper, and bankers' acceptances. These firms bought and sold fed funds, usually on a quarter-point spread, although the spread sometimes ran as high as a full percentage point because of Federal Reserve discount rate differentials between the East and West Coasts.[8] New York banks that found themselves with excess reserves in the afternoon wired funds to San Francisco before closing time in the East.

Banks used telegraphic transfers on behalf of their customers as well as for their own accounts. For example, prices on the New York Stock Exchange were communicated continuously to remote areas, from where investors or their local brokers could phone or wire instructions for transactions to be executed on the floor of the Exchange. Payment might then be arranged through the local bank, which could wire an order to its New York correspondent to serve as paying agent. Private wire systems had grown rapidly since they were first used by Wall Street "wire house" brokers for transactions within New York City in 1873. Private wires were extended to Boston and Philadelphia in 1879, Chicago in 1881, and San Francisco in 1901.[9] The situation in 1921 has been described as follows:

> Now there are about a thousand private wires in operation, tapping every city or locality of any importance in the United States and Canada. It is estimated that they are more than 500,000 miles in length. . . .
>
> Between New York and Chicago it is estimated that there are 100 leased wires; eight between Chicago and the Pacific coast; 100 between New York and Boston; 75 between New York and Philadelphia, Baltimore and Washington; 10 between New York and points south of Washington; 15 between New York and Montreal; 25 between New York, Pittsburgh and Buffalo; and about 25 from New York to other nearby cities. . . .
>
> The private wires now in operation are mainly employed by those who are engaged in business on the great speculative exchanges of the country, the New York Stock Exchange, the Chicago Board of Trade, the New York Cotton Exchange, and the smaller stock and commodity exchanges of the country, of which there are about fifty. . . .
>
> Then there are many large industrial and financial concerns that operate private wires in handling their business. The Federal Reserve Banks have a private wire system connecting them and their branches with each other and the Federal Reserve Board in Washington. The United States Steel Corporation and most of the big packers have their own private wire systems. Many of the large banks and banking firms lease private telephone circuits between New York and their home offices. ("The Nerves of Wall Street," *Commerce and Finance*, 22 June 1921, 879)[10]

Briefly, the funds transfer capabilities and competitive environment of the financial system were very similar between 1880 and 1930 to those of the 1980's. The next section examines the loan behavior of banks at the end of the earlier period, following a summary of their principal liabilities.

Bank loans in the 1920's

A substantial proportion of the liabilities of the money center banks paid interest that varied more or less with money market rates. Bankers' balances continued to be an important source of funds for

7. James G. Cannon, *Clearing-Houses: Their History, Methods and Administration* (New York: D. Appleton and Company, 1908), 235–36.

8. Parker B. Willis, *The Federal Funds Market: Its Origin and Development*, 4th ed. (Boston: Federal Reserve Bank of Boston, 1970).

9. J. Edward Meeker, *The Work of the Stock Exchange*, rev. ed. (New York: Ronald Press Company, 1930), 434–35.

10. Quoted by Meeker, *Work of the Stock Exchange*, 435–36.

large banks even after the Federal Reserve Act of 1913 required the legal reserves of national and other Federal Reserve member banks to be held with Federal Reserve Banks. The deposits of other banks averaged 19, 21, and 15 percent of the total deposits of member banks in New York City, Chicago, and reserve cities, respectively, during the 1920's. The more aggressive banks also paid interest on large nonbank demand deposits, although rates on these apparently did not vary a great deal.[11] Finally, by 1929 savings and time deposits (including negotiable and nonnegotiable certificates of deposit) made up 28 percent of the total deposits of New York City, Chicago, and reserve city banks.[12]

The top portion of Table 1 shows how these funds were allocated among various loan categories in the 50 or 60 largest cities.[13] A small but important category was loans to banks, especially by New York to the South and West. Interbank loans were a common feature of the relationships between city and country correspondents. Lines of credit were common. Oliver Lockhart wrote in 1921 that "General arrangements for borrowing are usually made at the time of opening correspondent relations. In recent years an investigation of the credit standing of the depositing bank is regularly made before the acceptance of the account. . . . The line of credit is adjusted to the average balance carried by the depositing bank, as is the practice in individual loans."[14] Most correspondent loans had maturities between 60 and 90 days and paid rates close to prime commercial paper rates.

The largest item in Table 1 is "unsecured [time] paper with one or more individual or firm names." These were predominantly short-term business loans of the kind that dominate the modern "commercial, industrial, and agricultural production" category in the lower portion of the table. The discounting of self-liquidating trade paper has never been as important in the United States (or elsewhere) as suggested by extensive textbook treatments of the subject. The actual application of the commercial loan theory of banking—whereby banks discount readily marketable "real" bills of exchange that mature simultaneously with the sale of goods financed by the loans, thus providing banks with safe and genuinely liquid assets and at the same time preventing excessive credit expansion by the banking system—must take its place with honesty, good workmanship, and flexible wages as something that for every generation was common in their grandparents' time but no longer exists.[15] Contemporary

11. This assumes that banks were more obedient to clearinghouse rate-fixing agreements after the Federal Reserve's intervention than before. For New York Clearing House demand deposit rates between 1918 and 1933, see Figure 1 of James M. Boughton and Elmus R. Wicker, "The Behavior of the Currency-Deposit Ratio During the Great Depression," *Journal of Money, Credit, and Banking* 11 (November 1979): 405–18.

12. Sources of these data are given and "reserve cities" are defined in the next footnote. The vigorous rate competition for time deposits in the 1920's is discussed by Charles M. Linke, "The Evolution of Interest Rate Regulation on Commercial Bank Deposits in the United States," *National Banking Review* 3 (June 1966): 449–69.

13. The upper and lower portions of Table 1 differ because the best loan data for large banks (which correspond roughly to banks in large cities) in the 1920's and before were reported by the Comptroller of the Currency for "reserve city" banks and "central reserve city" banks but more recently by the Federal Reserve for "large weekly reporting banks." The former classification may be explained as follows.

    The National Banking Act of 1863 required federally chartered banks to hold specified minimum cash reserves, except that, recognizing existing correspondent banking practices, "country" banks could satisfy three-fifths of their reserve requirements by deposits with "reserve city" banks, which in turn could keep half of their required reserves as deposits with "central reserve city" banks. Reserve requirements were 15 percent of deposits for country banks and 25 percent of deposits for others. The Federal Reserve Act required national banks (and others that chose to join the Federal Reserve System) to keep their reserves with Federal Reserve Banks, but retained the National Banking Act's classification of country, reserve city, and central reserve city banks for purposes of reserve requirements. In 1914, there were 3 central reserve cities (New York, Chicago, and St. Louis) and 49 reserve cities. By 1928, because of reclassifications, there were 2 central reserve cities (New York and Chicago) and 64 reserve cities. (See Board of Governors of the Federal Reserve System, *Banking and Monetary Statistics, 1914–1941* [Washington, D.C.: Board of Governors of the Federal Reserve System, 1943], 401.) The reporting dates in Table 1 were chosen for comparability of season and stage of the cycle (expansion but not peak).

14. Oliver C. Lockhart, "The Development of Interbank Borrowing in the National System, 1869–1914," 2 pts., *Journal of Political Economy* 29 (February, March 1921): 138–60, 222–40. The quotation is from p. 156.

15. The inadequacy of the commercial loan theory as a description of contemporary and previous American banking practice was the subject of Waldo F. Mitchell, *The Uses of Bank*

Table 1
PERCENTAGE DISTRIBUTION OF LOANS OF SELECTED BANKS, END OF JUNE

National banks in central reserve and reserve cities	1922	1928
Demand (call) loans		
Unsecured paper with one or more individual or firm names	4.6	4.5
Secured by stocks and bonds	17.5	21.6
Secured by other personal securities, including merchandise and warehouse receipts	3.2	3.2
Time (fixed-maturity) loans		
Unsecured paper with one or more individual or firm names	48.5	37.3
Secured by stocks and bonds	15.4	19.3
Secured by other personal securities, including merchandise and warehouse receipts	8.2	6.2
Secured by real estate	.9	6.1
Bankers' acceptances	1.7	1.7
Memo: Loans to banks	n.a.	3.2
By New York City banks	n.a.	5.5
Large weekly reporting banks	**1969**	**1981**
Loans, by category		
Brokers, dealers, and others for purchasing and carrying securities (including federal funds)	4.6	3.4
Banks (including federal funds)	4.0	7.5
Other federal funds sold	*	.6
Bankers' acceptances and commercial paper	.3	1.0
Commercial, industrial, and agricultural production	45.7	38.6
Real estate	19.0	25.2
Consumer	11.2	15.2
Nonbank financial	6.5	5.5
Other	8.6	3.0

* Less than one-half of 1 percent.
n.a.—Not available.
NOTE: Percentages may not add to 100.0 because of rounding.
SOURCES OF PRIMARY DATA: *Annual Reports of the Comptroller of the Currency.* *Federal Reserve Bulletins.*

observers complained throughout the 19th century that banks lent excessive amounts in the forms of government bonds and unsecured and nonmarketable promissory notes.[16] One of the Federal Reserve Act's goals was a return to the mythical state of the commercial loan theory, and economists marveled at the Federal Reserve System's early attempts "to change the commercial credit practices of this country in directions thought to be an improvement"[17] by offering preferential discount rates on trade acceptances and other domestic instruments similar to the bills of exchange common only in the finance of international trade. But banks and borrowers persisted in their old (and still current) reliance on secured and unsecured nonmarketable promissory notes, which were formally short-term but whose liquidity was doubtful because they were repeatedly renewed (and expected to be renewed) as part of long-term customer relationships.

The often-renewed commercial call loans also lacked genuine liquidity. However, the short-term contractual nature of business loans, which permitted the frequent adjustment of loan rates (daily in the case of call loans, whether renewed or not), allowed rates of return on assets to vary with the rates on their volatile managed liabilities and thus protected banks against the interest rate risk that arises from unmatched asset and liability maturities. Real estate loans were also short-term, national banks before 1927 being limited to maturities of no more than one year on these loans.[18] The rise in real estate loans between 1922 and 1928 occurred almost entirely after the McFadden Act of 1927 extended the maximum maturity to five years and in other ways lessened official interference with national bank lending on real estate.[19]

But the most liquid form of bank investment was the stock exchange call loan. Nearly all of the demand loans secured by stocks and bonds in Table 1 went to brokers and dealers. These loans "are made by banks to brokers who keep no deposit account with the bank. There being no deposit relationship, the bank feels at perfect liberty to call such loans whenever the need arises, and those loans are the first to be called if the bank must retrench."[20] Bank loans had long been negotiated on the floor of the New York Stock Exchange, and in 1869 a special *money post* was provided to brokers who specialized in arranging loans to other brokers and dealers on behalf of their bank clients. In 1917 the money post was replaced by the *money desk*, which added a clerical establishment to assist in the communication of the borrowing and lending needs of Exchange members and also for handling communications between banks and their floor brokers. "Upon learning the daily clearing-house results, bank officers in New York having surplus funds available

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Funds (Chicago: University of Chicago Press, 1925).

The Bank of New York opened June 9, 1784, with the announcement that it would discount notes and bills "at six per cent. per annum; but no discount will be made for longer than thirty days, nor will any note or bill be discounted to pay a former one." But we soon find the bank buying U.S. Government bonds, extending and renewing loans to Director Alexander Hamilton's Society for Establishing Useful Manufactures, and granting long-term loans to the state. (See Allan Nevins, *History of the Bank of New York and Trust Company, 1784 to 1934* [New York: Bank of New York and Trust Company, 1934], 15–25.) Bray Hammond wrote that such practices were common in 1800, although "the tradition of short-term credit continued to be held in pious respect and bankers liked to pretend that they were faithful to it" (*Banks and Politics in America, from the Revolution to the Civil War* [Princeton: Princeton University Press, 1957], 192). It is not enough merely to say that banks have never lived up (or down) to the commercial loan theory. There has in fact never been any intention to do so. Early banks were chartered by national or state governments for the purpose of financing those governments, the most notable examples being the Bank of England (where the overdraft was also widely used) and the First and Second Banks of the United States.

16. For examples, see Lloyd W. Mints, *A History of Banking Theory in Great Britain and the United States* (Chicago: University of Chicago Press, 1945), chaps. 8, 9, 11.

17. Luther Harr and W. Carlton Harris, *Banking Theory and Practice*, 2d ed. (New York: McGraw-Hill Book Company, 1936), 433.

18. The liquidity of real estate mortgages was greatly increased by the practice, especially in the case of large loans, of placing the mortgage "as security in trust and issuing real estate bonds against the mortgage in convenient denominations," usually to depositors (Rollin G. Thomas, *Modern Banking* [New York: Prentice-Hall, 1937], 138).

19. See National Industrial Conference Board, *The Banking Situation in the United States*, by Ralph A. Young and assistants (New York: National Industrial Conference Board, 1932), 98. Thomas, *Modern Banking*, 137, reports that state banks held more than three times the real estate loans of national banks, expressed as proportions of total loans and investments.

20. Harr and Harris, *Banking Theory and Practice*, 176.

for call loans inform their brokers who make loans on the floor of the exchange."[21] About half of the time loans secured by stocks and bonds also went to brokers and dealers.[22] These and some of the call loans were arranged through brokers off the Exchange. Most stock market loans were made by New York City banks. But substantial amounts were extended directly to brokers and dealers by banks in the interior and also by nonfinancial businesses.[23]

In summary, substantial parts of bank assets and liabilities paid returns and incurred costs that varied with other short-term rates. Banks were nicely hedged against interest rate risk. But no one was protected against, nor could anyone have foreseen, the withdrawal of 40 percent of Federal Reserve credit between October 1929 and October 1930, the currency drains and bank panics of 1931 and 1933, the failure of nearly half the banks between 1929 and 1933, and the loss of 37 percent of bank deposits and 55 percent of bank loans during the same period.

Changes in bank loan practices during the 1930's and 1940's

Davis Dewey and Martin Shugrue wrote in 1922 about business call loans that

> It is not unusual for loans of this kind to run for 6 months or a year or even longer. There is usually a mutual understanding (not a written agreement) between the bank and its customer that demand for payment of the note will not be made until some time which is convenient to the borrower. . . . A large commercial bank in Boston states that during its fifty years of existence it has not served a single notice on a borrower for payment of a demand loan and this case is probably by no means exceptional. (*Banking and Credit*, 177-78)

Not so during the Great Depression as banks and other creditors pressed for the repayment of debt with no thought of customer relationships or of anything else except survival. The effects of this trauma on bank loan contracts lasted 40 years and some vestiges (such as "the" prime rate of recently uncertain meaning) still remain. One of the earliest effects was the increased use of explicit long-term loans—which borrowers wanted in order to make sure of funds for the full periods for which they were needed, having learned not to count on renewals,[24] and which banks were willing to supply because they had turned to new sources of liquidity, having learned that call loans are not in fact callable during general liquidity crises.[25]

Banks accumulated substantial excess reserves both because of their low opportunity costs during the low-interest-rate decades of the 1930's and 1940's and in fear of another bank run or other attack on their reserve positions. Banks also attempted to improve their liquidity by shifting from loans to marketable government securities until the former had declined as a proportion of earning assets from about 70 percent in 1929 to 40 percent in 1940. Excess reserves rose from 2 to 91 percent of required reserves during the same period.

Banks extended few loans but their liquid cash and security positions made them willing to extend a higher proportion of long-term loans than in the 1920's. There were also more strings attached. Banks imposed covenants on long-term loans similar to those required by bondholders, including restrictions on dividend payments, minimum working capital requirements, liens on property, limits on other debt, limits on pledges of property to secure other debt, and the greater use of security in the forms of

21. Davis R. Dewey and Martin J. Shugrue, *Banking and Credit* (New York: Ronald Press Company, 1922), 176.

22. The estimated proportions of loans secured by stocks and bonds that went to brokers and dealers are based on estimates in Thomas, *Modern Banking*, 116, and Ray B. Westerfield, *Money, Credit and Banking* (New York: Ronald Press Company, 1938), 325.

23. See Margaret G. Myers, *Origins and Development*, vol. 1 of *The New York Money Market*, ed. Benjamin H. Beckhart (New York: Columbia University Press, 1931), 266-69.

24. The increased demand for long-term bank loans as a proportion of long-term debt has also been partly attributed to the increased costs of issuing bonds following the Securities Exchange Acts of 1933 and 1934. See Neil H. Jacoby and Raymond J. Saulnier, *Term Lending to Business* (New York: National Bureau of Economic Research, 1942), chap. 5; and George S. Moore, "Term Loans and Interim Financing," in *Business Loans of American Commercial Banks*, ed. Benjamin H. Beckhart (New York: Ronald Press Company, 1959), chap. 9.

25. *Glendower*: I can call spirits from the vasty deep.
Hotspur: Why, so can I, or so can any man;
But will they come when you do call for them?
(*King Henry IV, Part I*, act 3, sc. 1)

Table 2
COMMERCIAL BANK LOAN AND MONEY MARKET RATES, 1919-29 AND 1953-83

	Date	R_{BL}	R_{CF}	R_{CP}	ΔR_{BL}	ΔR_{CF}	ΔR_{CP}
(T)	May 1919	5.65	5.26	5.38			
(P)	February 1921	6.94	7.05	8.42	1.29	1.79	3.04
(T)	September 1922	5.21	4.26	4.20	-1.73	-2.79	-4.22
(P)	September 1923	5.61	5.14	5.50	.40	.88	1.30
(T)	August 1924	4.78	2.00	3.17	-.83	-3.14	-2.33
(P)	October 1926	5.19	4.86	4.72	.41	2.86	1.55
(T)	November 1927	4.87	3.50	4.07	-.32	-1.36	-.65
(P)	October 1929	6.21	5.96	6.42	1.34	2.46	2.35
(P)	December 1953	3.65	n.a.	2.78			
(T)	March 1955	3.43	1.34	1.32	-.22		-1.46
(P)	December 1957	4.74	2.98	4.07	1.31	1.64	2.75
(T)	June 1958	4.06	1.02	1.60	-.68	-1.96	-2.47
(P)	December 1959	5.25	3.99	4.98	1.19	2.97	3.38
(T)	December 1961	4.85	1.93	2.97	-.40	-2.06	-2.01
(P)	December 1966	6.20	5.48	6.15	1.35	3.55	3.18
(T)	May 1967	5.79	3.92	4.83	-.41	-1.56	-1.32
(P)	February 1970	8.70	9.20	8.90	2.91	5.28	4.07
(T)	February 1972	5.52	3.24	4.06	-3.18	-5.96	-4.84
(P)	August 1974	12.40	12.13	12.02	6.88	8.89	7.96
(T)	May 1976	7.44	5.03	5.32	-4.96	-7.10	-6.70
(P)	May 1980	17.75	12.98	13.68	**10.31**	7.95	8.36
(T)	August 1980	11.56	9.23	9.22	**-6.19**	-3.75	-4.46
(P)	August 1981	21.11	18.25	18.68	**9.55**	9.02	9.46
(T)	February 1983	10.20	8.50	8.47	**-10.91**	-9.75	-10.21

Definitions

P,T = peak and trough dates of R_{BL}.

R_{BL} = average rate on short-term business loans. (Data for 1953-83 have been adjusted for changes in the Federal Reserve's quarterly Survey of Terms of Bank Lending to make rates comparable over time.)

R_{CF} = average rate on stock exchange call loans (1919-29) and federal funds (1955-83).

R_{CP} = average rate on 4- to 6-month prime commercial paper (average of 3- and 6-month commercial paper rates after 1979), converted to a 360-day yield basis to be comparable with R_{BL} and R_{CF}.

n.a.—Not available.

NOTE: R_{BL} was reported for the 15th of each month during 1919-29, the first half of one month in each quarter during 1953-76, and the first business week in the middle month of each quarter during 1977-83. The other rates apply to approximately the same dates as R_{BL}, except that R_{CP} is reported for its own peaks and troughs based on reporting dates for R_{BL}.
Figures in boldface represent greater change in loan rate than in commercial paper rate.

SOURCE OF PRIMARY DATA: Board of Governors, Federal Reserve System (*Banking and Monetary Statistics, 1914-1941* and *1941-1970*; *Annual Statistical Digests*; and *Federal Reserve Bulletins*).

warehouse receipts and the assignment of accounts receivable.[26]

Banks also required implicit or explicit long-term deposit commitments from their borrowers (short-term as well as long-term), partly in order to achieve stability in their reserve positions and lending capabilities, and also as part of a policy of competition for deposits through preferential loan terms, a practice that became more important after the prohibition of interest on demand deposits in 1933. All of these developments acted to restore, with greater strength than ever, the customer relationships that had been interrupted by the Great Depression. Banks increasingly provided insurance against the premature loss of financing to borrowers who in exchange insured banks against bad loans and the loss of deposits, until business loans with maturities of one year or more (term loans) had risen from almost nothing in 1929 to nearly one-third of business loans in 1940.[27]

These mutual insurance arrangements begun in response to the catastrophic events of 1929–33 were continued and perhaps strengthened by the stable conditions that prevailed between about 1950 and the mid-1960's, even when interest rates rose and excess reserves and security holdings declined. Relatively steady economic growth, combined with relatively steady monetary and fiscal policies, meant a stable interest rate and bank reserve environment in which banks could safely extend long-term fixed-rate loans.

Familiar developments

The often-observed tendency of commercial bank loan rates to be less variable than other short-term (or "money market") rates has been rationalized in a variety of ways. First, it might be in the interests of a well-diversified bank and a borrower engaged in repeated short-term ventures, such as the purchase and sale of goods, for the bank to offer insurance against "excessive" (as measured by money market rates) fluctuations in the future cost of funds. That is, there may be an understanding between bank and borrower that the loan rate will be higher (the insurance premium) but less variable than in the case of borrowers with no such implicit contract.[28]

Second, the bank-customer relationships implied by repeated loan renewals suggest that the current accommodation of prospective borrowers by a bank influences the bank's future deposits and loan demands. These effects are due both to the costs to banks of acquiring credit information on new borrowers and to the search costs and other borrower costs of shifting from one source of funds to another.[29] This in turn suggests that increases in loan demands that are expected to be continued into the future will induce smaller increases in loan rates than would occur in the absence of customer relationships because future loan demands and deposit supplies are strengthened by current loan supplies.[30] The intertemporal effects of customer relationships on current loan rate policies are strengthened by interest rate ceilings that restrict bank abilities to attract funds by other means. These arguments are supported by the suggestion that the current accommodation of long-term, steady customers exerts favorable influences on the variances of future deposits, loan demands, and bank profits.[31]

26. For a discussion of protective provisions in long-term loans, see Neil H. Jacoby and Raymond J. Saulnier, *Business Finance and Banking* (New York: National Bureau of Economic Research, 1947), chaps. 5, 6; and Moore, "Term Loans and Interim Financing."

27. Jacoby and Saulnier, *Term Lending to Business*, 1.

28. This argument has been made by Joel Fried and Peter Howitt, "Credit Rationing and Implicit Contract Theory," *Journal of Money, Credit, and Banking* 12 (August 1980): 471–87. Dewey and Shugrue earlier pointed out in connection with call loans that "When there is a mutual understanding between the borrower and lender that the loan will not be called until it is convenient for the borrower, the rates usually do not vary much from those on time loans. [Time loan rates were less variable than call loan rates.] When no such understanding exists, however, as in the case of brokers and traders in the produce and stock exchanges, a bank will generally make a call loan at a lower rate of interest than is charged for a time loan" (*Banking and Credit*, 178).

29. The customer relationship was mentioned by most of the early writers cited above and has more recently been emphasized by Donald R. Hodgman, *Commercial Bank Loan and Investment Policy* (Champaign: University of Illinois, Bureau of Economic and Business Research, 1963).

30. By a similar line of argument, reductions in loan demand induce smaller reductions in loan rates in the presence of customer relationships. See J. H. Wood, *Commercial Bank Loan and Investment Behaviour* (London: John Wiley & Sons, 1975).

Finally, the possibilities of "adverse selection" and "moral hazard" suggest that increased loan rates in the presence of uncertainty might reduce the bank's expected profits either by screening out the least risky borrowers or by providing an incentive for existing borrowers to undertake riskier projects—thereby inducing banks to rely on means other than interest rates to ration credit.[32]

The events intended to be explained by these theories are summarized in Table 2 for 1919-29 and 1953-83. These periods were chosen because bank loan rate data first became available on a regular basis in 1919 and there were no significant cyclical fluctuations in interest rates between 1929 and 1953—these years being dominated first by a strong downward trend in rates until early in World War II and then by a Federal Reserve bond support program until 1953. The columns headed R_{BL} and R_{CF} list an average short-term business loan rate and the rate on the primary source of short-term bank reserve adjustments (call loans during 1919-29 and fed funds during 1953-83) at the peaks (P) and troughs (T) of R_{BL}. The R_{CP} column lists the prime commercial paper rate at the peaks and troughs of that rate (limited to reporting dates for R_{BL}), which have often led the turning points of R_{BL} listed in the table.

Notice that during 1919-29 the average short-term business loan rate was less variable than other short-term rates. Nevertheless, banks were well hedged against interest rate risk because the rate of return on their large investments in stock exchange call loans varied with other money market rates, including the costs of bankers' balances and other bank liabilities.

The lower portion of Table 2 shows that business loan rates continued to vary less than other short-term rates in the 1950's and 1960's. But trouble was brewing. Instead of R_{BL} being an understatement of the variability of returns on bank assets, as in the 1920's when call loans were important, it had become an overstatement because of the continued growth of long-term loans (consumer and real estate loans as well as business term loans) that had begun in the 1930's. The maturity mismatch of bank assets and liabilities was not dangerous as long as interest rates were fairly steady. Furthermore, bank liabilities were concentrated in demand and time deposits with constant or slowly changing interest rate ceilings.

But the growth of fed funds, repurchase agreements, and short-term time deposits (especially certificates of deposit) that are free of interest regulation means that the preponderance of bank liabilities once again, as in the 1920's, pay money market rates. This in turn means that, with the return to the pre-1930 world of volatile interest rates, banks now have greater incentive to achieve asset returns that vary with money market rates than during the period of tranquil interest rates existing between the 1930's and the late 1960's. But how? For banks, even money center banks, are less important lenders directly to the money market now than before 1930. Table 1 indicates that in 1969 only about 7 percent of the loans of the largest banks were one-day loans to the money market.[33] This had grown to about 9 percent in 1981 but was still much less than the 17.5 percent of 1922 and 21.6 percent of 1928 for roughly comparable banks. Other factors tending to reduce the flexibility of asset returns compared with the 1920's have been large increases in the volume and maturities of real estate loans, the growth of consumer installment loans, and the growing importance of term loans.

There were two ways in which banks might have made asset rates of return vary with those on liabilities. First, they might have shifted from business, real estate, and consumer loans toward money market loans. The lower portion of Table 1 indicates that there may have been a small shift in this direction, although its effects on asset return flexibility were offset to the extent that the increase in real estate loans took the form of fixed-rate mortgages. Second, banks might have continued to lend to the same people for the same purposes but for shorter terms and/or at rates of interest tied to

31. Edward J. Kane and Burton G. Malkiel, "Bank Portfolio Allocation, Deposit Variability, and the Availability Doctrine," *Quarterly Journal of Economics* 79 (February 1965): 113-34.

32. Joseph E. Stiglitz and Andrew Weiss, "Credit Rationing in Markets with Imperfect Information," *American Economic Review* 71 (June 1981): 393-410.

33. This assumes that 80 percent of fed funds and other loans to banks and brokers were for one day or had rates that changed daily.

Table 3
COMMERCIAL AND INDUSTRIAL LOANS: AVERAGE MATURITIES AND PERCENTAGES WITH FLOATING RATE

	1977	1978	1979	1980	1981	1982	1983[1]
Short-term loans							
Amount (billions of dollars) . . .	24.7	30.6	31.8	47.8	83.9	143.6	117.2
Average maturity (months) . . .	2.2	1.9	2.1	1.8	1.5	1.5	1.1
Percent with floating rate	45	41	47	45	39	29	32
Long-term loans							
Amount (billions of dollars) . . .	4.6	5.2	6.1	8.2	12.1	15.2	12.2
Average maturity (months) . . .	44.1	45.1	47.3	44.9	48.9	48.4	54.9
Percent with floating rate	49	53	57	65	73	70	73

1. First three quarters.

NOTE: From the Federal Reserve's Survey of Terms of Bank Lending, which is based on loans during the first full business week of the middle month of each quarter at the 48 largest banks and about 300 banks selected at random. Reported loan volumes are estimates of all lending in each category by U.S. commercial banks during the survey period, based on the loans of the surveyed banks relative to all banks as shown on call reports. (See *Federal Reserve Bulletin* 63 (May 1977): 442-55 for a description.) The average maturities in this table differ from those reported in the survey by taking account of zero-maturity demand loans.

SOURCE: *Federal Reserve Bulletins.*

money market rates. That is in fact what they have done, especially for business loans—specifically, as shown in Table 3, by increasing the proportion of short-term loans (with maturities less than one year), reducing the maturity of short-term loans, and increasing the proportion of long-term loans with floating rates.[34] These changes are reflected in Chart 1, which shows that loan rates, after remaining fairly steady in the face of increasingly volatile money market rates, began in the late 1960's to vary nearly as much as, and then in the late 1970's to vary more than, the latter. The same story is told in Table 2, where the boldface entries correspond to interest rate movements during which bank loan rates have varied more than the rate on commercial paper. Banks are no longer willing to bear the risk of interest rate fluctuations for their business customers—because of the combined effects of (1) the greater interest rate volatility of the 1970's and 1980's (compared with the 1930's to 1960's) and (2) the decreased importance of money market assets (compared with the 1920's) that provide an alternative means of hedging interest rate risk. Furthermore, the end of Regulation Q's effectiveness has reduced incentives to compete for deposits by means of steady loan rates.

34. These data are available only from the inception of the Federal Reserve's Survey of Terms of Bank Lending in its present form in 1977. For a discussion of changing bank loan practices during the 1970's, especially the growing importance of floating rates, which "have probably been the most important innovation in bank lending since the advent of the term loan," see Randall C. Merris, "Business Loans at Large Commercial Banks: Policies and Practices," *Economic Perspectives*, Federal Reserve Bank of Chicago, November/December 1979, 15-23.

Summary

The above discussion was separated into three periods determined by differences in the volatility of interest rates and the effects of those differences on bank loan contracts: (1) The volatile pre-1930 world saw vigorous bank competition for liabilities whose costs varied closely with money market rates. Banks avoided interest rate risk in that environment

by investing primarily in short-term business loans and, most important, stock exchange call loans. (2) The interruption of loan renewals and the large-scale (though often futile) loan calls during the Great Depression led to the growth of long-term fixed-rate loans and the reestablishment and strengthening of customer relationships as banks and their borrowers sought to insure themselves against future losses of finance. A relatively stable interest rate and bank reserve environment enabled these mutual insurance arrangements to survive through the 1960's. (3) In recent years, the return of volatile interest rates has led to the restoration of bank liability management and to bank loan contracts providing for asset returns that vary with the costs of money market liabilities. The main difference between the 1920's and the 1980's is that the principal methods by which banks hedge interest rate risk are now short-term and variable-rate commercial and industrial loans, instead of stock exchange call loans as in the earlier period.

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Texas Agricultural Productivity: Is Research the Remedy?

*By Hilary H. Smith**

The fundamental natural resources of Texas, land and water, continue to diminish. Rapidly growing population converts prime agricultural land to urban and suburban use, putting heavy demands on the existing water supplies. Texas trails only California in the number of irrigated acres and, unlike California, uses large amounts of subsurface water for irrigation. But with higher energy costs and depletion of water stocks, water from subsurface sources is becoming increasingly noneconomic. Continuing the experience of the 1970's, Texas agriculture in the future will have to struggle to maintain even current productivity and output.

One possible solution to these problems is to conserve the existing resource base. But that would require extensive government intervention in land and water use—an anathema if imposed by regulation and far too costly if achieved by economic incentives. Another possibility is to rely largely on state-supported agricultural research to find the keys to a more productive agriculture in a less-endowed future. Numerous studies have shown that investment in agricultural research seems to pay off handsomely, at least in terms of return on the dollar. But these studies beg the essential problem. High rates of return to research, measuring the per-dollar effects of research on output, may obscure the fact that these returns are negligible relative to overall output. If that impact is small given the level of research, even with a high rate of return on the investment, then either the amount of research undertaken needs to be greatly increased or the existing research has to become a great deal more productive.

This article examines the likely impact of research on agricultural output in Texas. First, Texas agricultural productivity movements and some of the factors bearing upon them are examined. Next, empirical evidence on the relationship between publicly supported agricultural research and agricultural output is reviewed and critiqued. This is followed by a simulation of the effects of agricultural research on Texas agriculture.

The simulation uses different values for two factors that determine the influence of research on the

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output of food and fiber. One factor is the growth of expenditures for agricultural research, a proxy for research effort. The second is the response of output to increases in spending for agricultural research.

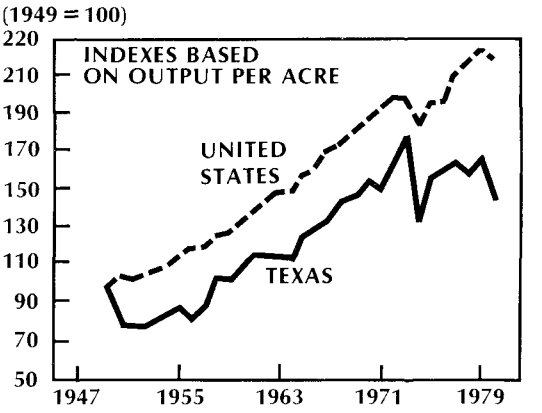
Indications are that even for optimistic values of output responsiveness and above-historical-average increases in research expenditures, only modest gains in agricultural output result. If research is going to have significant effects on output, then, dramatic changes in the growth of funding, greatly increased research efficiency, or both will be necessary. Is this likely? With enormous federal budget outlays for controlling commodity surpluses in these times of austere state and federal nondefense budgets, it is difficult to make the case to the public that agricultural productivity needs to be maintained through research. Moreover, there is no constituency for this essentially long-term research because public awareness of Texas agriculture's long-term problems is probably quite low. Outside the area of government funding, one must depend on the private sector and the possibility of a technological breakthrough.

Need for increased agricultural productivity

To remain competitive in the market for agricultural products, Texas must keep up with productivity increases in the United States and overseas. Increasing agricultural productivity means more output per unit of input.[1] Chart 1 shows the movement of indexes of U.S. and Texas agricultural output per acre for the postwar period. From 1969 onward, Texas agricultural productivity has not followed the U.S. productivity growth but, rather, has moved erratically up and down with no clear trend. With lagging productivity, Texas agriculture is threatened with the possibility of becoming a high-cost producer relative to other agricultural exporters, unable to retain customers in very competitive agricultural markets. This is a disturbing development for the state because agriculture is an important Texas industry.[2]

Chart 1

Agricultural Productivity



SOURCE OF PRIMARY DATA: U.S. Department of Agriculture.

Non-weather-related productivity increases in agriculture are the result of improvements in the quality of labor, more efficient agricultural techniques, or technological changes in agricultural capital (broadly defined as machinery, pesticides, fertilizers, seed, feed, and so on). Agricultural research can be the prime mover for improvements in both agricultural techniques and technological change. It is likely, however, that the output effects of agricultural research in any one year will occur with some time lag and over the course of several years.

Agricultural research is conducted largely at various institutions rather than by individual scientists or farmers. To boost productivity through agricultural research, these institutions and the

1. Agricultural productivity is usually thought of as total-factor productivity: total output divided by total inputs. To be consistent with most of the empirical studies, a partial measure of productivity is used here: output per acre. For the definition of output, see Fred C. White and Joseph Havlicek, Jr., "Rates of Return to Agricultural Research and Extension in the Southern Region," *Southern Journal of Agricultural Economics* 11 (December 1979): 108.

2. Although only about 5 percent of the gross state product, Texas agriculture generates $10 billion of agricultural products a year, and each $1.00 of sales generates $3.40 of additional state economic activity (sources: Texas Crop and Livestock Reporting Service, *1981 Texas County Statistics*, Bulletin 204 [Austin, Tex.: Texas Department of Agriculture and U.S. Department of Agriculture, 1982], and Texas Agricultural Experiment Station, *Texas Agriculture in the 80's: The Critical Decade* [College Station, Tex., 1980]).

means for increasing their research output need to be identified.

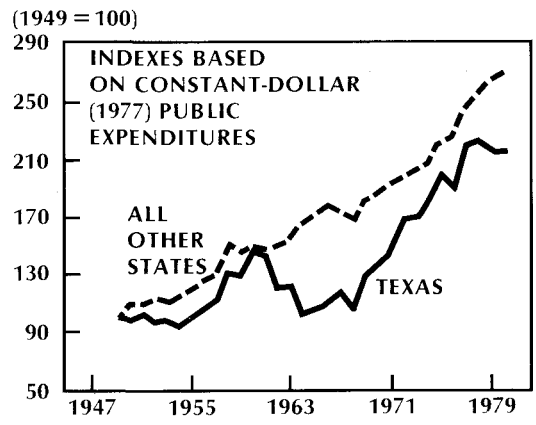
Agricultural research in Texas

Agricultural research is conducted mainly by publicly supported institutions at the state and national levels. There is also a large amount of privately funded agricultural research, for which little hard data exist.[3] At the state level, most of the publicly supported agricultural research is carried on by the agricultural experiment stations. The Texas Agricultural Experiment Station (TAES) is typical and is supported by both federal funds (in fiscal 1980, estimated to be at least 15 percent) and state funds (which supply most of the remainder). Small amounts of private grants and sales of products also make up experiment station income.

Public (federal and state) expenditures for agricultural research, adjusted for inflation, have grown erratically since the end of World War II. Chart 2 shows indexes of real public expenditures for agricultural research and related activities for Texas and for all the other states combined.[4] Texas agricultural research generally increased through the 1950's, reaching a peak in 1960. It then declined through much of the 1960's but moved upward through the middle 1970's. Over the 1949–80 period, growth in real research funding in Texas was not as robust as in the rest of the nation, but during the decade of the 1970's, Texas research funding grew more rapidly—3.9 percent compared with 3.3 percent.

Chart 2

Agricultural Research Expenditures



SOURCES: See footnote 4.

Agricultural research is difficult to quantify, but using yearly real expenditures for research as a proxy for research effort, it is clear that Texas agricultural research efforts have grown. The impact of such research on output is an empirical question.

3. In 1976 the Agricultural Research Institute surveyed 240 companies, and the respondents reported agricultural research expenditures of $575 million for the preceding year (source: U.S. Congress, Office of Technology Assessment, *An Assessment of the United States Food and Agricultural Research System*, Rept. OTA-F-155 [Washington, D.C.: Government Printing Office, 1981]). This compares with around $915 million of publicly supported agricultural research (sources: U.S. Department of Agriculture, Cooperative State Research Service, *Inventory of Agricultural Research, FY 1976 and Transition Quarter*, vol. 2 [Washington, D.C., 1977], and *The Budget of the United States Government, Fiscal Year 1976* [Washington, D.C.: Government Printing Office, 1975]).

4. Texas Agricultural Experiment Station expenditures compared with agricultural experiment expenditures of all other states. Data on experiment station expenditures are from various publications of the U.S. Department of Agriculture: Agricultural Research Administration/Service, *Report on the Agricultural Experiment Stations*; Cooperative State Research Service, *Funds for Research at State Agricultural Experiment Stations and Other Cooperating Institutions*; and Cooperative State Research Service, *Inventory of Agricultural Research*, vol. 2.

Two deflators were used. Labor costs were considered to be 71.18 percent of total expenditures, based on Joseph W. Murphy and Donald R. Kaldor, "The Changing Cost of Performing Agricultural Research: An Index Approach," in *Evaluation of Agricultural Research*, Proceedings of a Symposium Sponsored by North Central Regional Project NC-148, Minneapolis, May 12–13, 1980, Minnesota Agricultural Experiment Station Miscellaneous Publication no. 8 (Minneapolis: University of Minnesota, Agricultural Experiment Station, 1981), 193. The American Association of University Professors (AAUP) yearly percentage salary increase for "all ranks" was used as the deflator. Data for 1949 to 1972 are contained in Philip Lee Cline, "Sources of Productivity Change in United States Agriculture" (Ph.D. diss., Oklahoma State University, 1975). Data for years after 1972 were taken from the *AAUP Bulletin* and *Academe*. The remaining 28.82 percent of experiment station expenditures was deflated by the implicit price deflator for state and local government purchases of goods and services.

Studies of research effects on output

Production function (PF) studies have attempted to measure regionally, nationally, and internationally the effect of public agricultural research on agricultural output and the returns on investment to agricultural research.[5] All the studies examined here used a generalized Cobb-Douglas production function.[6] The relative strength of the inputs can be estimated using econometric techniques. When estimated in log-linear form, the coefficients on each of the input variables are elasticities.[7] With estimates of the input elasticities, the effect of increases in the levels of various inputs on agricultural output can be determined. A summary of selected U.S. regional and national PF studies is presented in Table 1. In these studies the internal rate of return (IRR) is the rate that will equate the flow of private benefits over time with the initial public outlay. The research coefficient is the elasticity of private agricultural output with respect to public agricultural research.

The listed rates of return are nothing short of remarkable, with the smallest being almost 7 percent while most range well above 30 percent. With these high rates of return, one would expect heavy participation in research by private firms. To a large degree this is true, but much of the benefits of agricultural research accrues to the public and cannot be captured by profit-oriented private firms: thus the long involvement of the public sector in funding agricultural research. The research coefficients show great variability as well but range up to .27. From these results, one would have to conclude that it would be a wise decision to invest in agricultural research.

There are some troubling aspects about this literature, however. First, the rates of return are calculated at the means of output and research, which may not be very meaningful when using the calculated rates of return as indications of future returns to current investment.[8] Using Texas as an example, the ratio of the arithmetic means of output and research for the 1949–80 period is around 328. The mean value of output approximately corresponds to the output in 1965, while the mean value of research is close to the level of expenditures in 1969. The ratio of the means corresponds to the ratio that existed in 1972. Further, the elasticity could be evaluated at the mean of the output-research ratio instead of the ratio of the means. This yields a value of 338, which is close to the value of the ratio in 1953 also. The rationale for evaluating the elasticity at any of these points is not clear. An argument can be made for evaluating the output-research ratio close to the end of the time series if

5. Studies of the effect of research productivity on agricultural output can be divided into two broad categories: ex *ante* (or before the fact) and ex *post* (after the fact) approaches. For the purposes of this article, only the ex *post* studies are pertinent. Within the ex *post* category, there are two methodologies: the consumer surplus (CS) and the production function (PF). The CS method cannot calculate research elasticities, so only the PF method is considered here.

6. The generalized Cobb-Douglas production function with output (Q), constant (w), capital (K), labor (L), land (A), and research (R) is

$$Q = w K^a L^b A^c R^d.$$

The superscripts here are termed coefficients, and their sum shows the nature of the returns to scale—that is, whether the production function has increasing (coefficient sum is greater than 1), decreasing (coefficient sum is less than 1), or constant (coefficient sum equals 1) returns to scale. Returns to scale indicate whether for a given increase in inputs, output increases less than proportionally (decreasing returns), more than proportionally (increasing returns), or in the same proportion (constant returns).

7. Log-linear form means that logarithms have been taken of each side of the equation. Elasticity measures the percentage change of one variable (here it would be agricultural output) in response to a 1-percent change in another variable (for example, one of the inputs in the present case).

8. The computation of the IRR begins with the estimation of the research coefficient (β), which is the elasticity of output (Q) with respect to research (R). Mathematically, the elasticity is

$$\frac{\partial Q}{\partial R}\frac{R}{Q} = \beta.$$

Rearranging terms gives the marginal product:

$$\frac{\partial Q}{\partial R} = \frac{Q}{R}\beta.$$

The estimate of β is determined econometrically, while the output-research ratio (Q/R) is typically evaluated at some measure of the means of output and research. The marginal product is the increase in output, in dollars, for a $1 investment in an input factor—in this case, research. Because this output increase takes place in the future, the "return" on research must be discounted to the present. The IRR is the rate of discount that will equate the research outlay of $1 in the initial period with the return (the marginal product, which is in the form of output increases) over a specified number of years.

Table 1
RATES OF RETURN AND RESEARCH COEFFICIENTS IN SELECTED AGRICULTURAL RESEARCH STUDIES

Author	Internal rate of return (Percent)	Research coefficient	Coverage
1. White and Havlicek	6.9–36.0	.038	National model (states)
2. White and Havlicek	40.0	.077 .135 (spillover)	National model (states)
3. White and Havlicek	39.8	.070 .065 (spillover)	Southern states
4. Davis and Peterson	37–100	.039–.070*	National model (states)
5. Norton	31– 85 (cash grains) 27– 62 (dairy) 56–132 (livestock) 30– 56 (poultry)	.073, .091** .041, .057 .122, .168 .017,* .071	National model (geoclimatic regions)
6. Sundquist, Cheng, and Norton	115 (corn)	.20 .06* (spillover)	23 states
	97 (wheat)	.27 .14 (spillover)	34 states
	118 (soybeans)	.24 .33 (spillover)	26 states
7. Cline and Lu	14.3	.0211	Texas and Oklahoma

1. Fred C. White and Joseph Havlicek, Jr., "Optimal Expenditures for Agricultural Research and Extension: Implications of Underfunding," *American Journal of Agricultural Economics* 64 (February 1982): 47–55.
2. Fred C. White and Joseph Havlicek, Jr., "Interregional Spillover of Agricultural Research Results and Intergovernmental Finance: Some Preliminary Results," in *Evaluation of Agricultural Research*, Proceedings of a Symposium Sponsored by North Central Regional Project NC-148, Minneapolis, May 12–13, 1980, Minnesota Agricultural Experiment Station Miscellaneous Publication no. 8 (Minneapolis: University of Minnesota, Agricultural Experiment Station, 1981), 60–70.
3. Fred C. White and Joseph Havlicek, Jr., "Rates of Return to Agricultural Research and Extension in the Southern Region," *Southern Journal of Agricultural Economics* 11 (December 1979): 107–11.
4. Jeffrey S. Davis and Willis Peterson, "The Declining Productivity of Agricultural Research," in *Evaluation of Agricultural Research*, 97–104.
5. George W. Norton, "The Productivity and Allocation of Research: U.S. Agricultural Experiment Stations, Revisited," in *Evaluation of Agricultural Research*, 105–15.
6. W. B. Sundquist, Cheng-Ge Cheng, and George W. Norton, "Measuring Returns to Research Expenditures for Corn, Wheat, and Soybeans," in *Evaluation of Agricultural Research*, 76–82.
7. Philip L. Cline and Yao-Chi Lu, "Efficiency Aspects of the Spatial Allocation of Public Sector Agricultural Research and Extension in the United States," *Regional Science Perspectives* 6 (1976): 1–16.

* Not significant statistically.
** Cross-section estimates for two different years.

the object is to make inferences about what the future returns to agricultural research will be. In the example for Texas, the output-research ratio in 1980 is 241—26 percent less than at the ratio of the means. Thus, evaluation at the means could lead to potentially misleading results.[9]

Second, the literature concentrates on estimating production functions of the Cobb-Douglas type for various aggregations of agricultural output. The usefulness of estimating aggregate production functions generated much debate within the agricultural economics literature more than 20 years ago. Arguments centered around several problems: estimating production functions from nonexperimental data,[10] specification bias,[11] and distortions produced by aggregation.[12] In summary, the conceptual and empirical problems with using an aggregate agricultural production function render the estimates somewhat suspect.

Third, a common practice in the literature is to define all the traditional production function variables (output, labor, and capital) on a per-acre or per-farm basis. Dividing the output and inputs in this way creates a production function based on the average acre or farm. Research, however, enters the production function in aggregate form because each farmer can use the benefits of all the applicable research without interfering with any other farmer's use of the same research results. Such simultaneous use is impossible with the traditional inputs.

Dividing output and traditional inputs by the number of acres or farms and including research as an aggregate, while seemingly theoretically appealing, can lead to unusual results during estimation. A production function, using per-acre or per-farm variables, can be rearranged so that land or farms appears explicitly and none of the inputs are divided by land/farms. For example, the generalized Cobb-Douglas function with constant (d), capital (K), labor (L), and output (Q) all on a per-acre (A) basis plus research (R) is

$$(Q/A) = d\,(K/A)^a\,(L/A)^b\,R^c.$$

Rearrangement yields

$$Q = d\,K^a\,L^b\,R^c\,A^{(1-a-b)}.$$

Note that the coefficient on the acres (A) input is $1-a-b$. With a and b restricted by economic theory to be positive, the larger the values of a and b, the smaller is the coefficient for land.

If the sum of the estimated nonresearch coefficients is close to 1 (as it is in many of the studies), the implied coefficient on either land or farms is near zero. If $(a+b)$ is greater than 1, the coefficient for land is negative. The nonresearch coefficient estimates frequently sum to greater than 1 in the literature, meaning that land or farms would have implied negative effects on agricultural output—a highly unlikely result.

Fourth, the number of lagged values for the research term in the econometric specification is frequently determined by the data or by whim. It is always hypothesized that research in the current period will affect future productivity, but length of lag and the proportioning of the impact are handled in an *ad hoc* manner and are different in almost every study. The length-of-lag structure sometimes seems to be a function of data. Time-series studies with long runs of data usually postulate long-lasting lag effects, while cross-sectional studies posit shorter lag structures. Some studies try several lag structures and report the one that works best or seems representative. Econometrically, there are problems with using distributed-lag models without sound *a priori* theoretical justification for choosing a particular lag structure.[13]

Fifth, the model specification in agricultural

9. A similar case can be made for cross-sectional studies that evaluate the elasticities at the means. That is, states whose values of output and research are far from the mean will have different values for the output-research ratio and hence a different IRR.

10. Zvi Griliches, review of *Agricultural Production Functions*, by Earl O. Heady and John L. Dillon, *American Economic Review* 52 (March 1962): 280–83.

11. Zvi Griliches, "Specification Bias in Estimates of Production Functions," *Journal of Farm Economics* 39 (February 1957): 8–20.

12. James S. Plaxico, "Problems of Factor-Product Aggregation in Cobb-Douglas Value Productivity Analysis," *Journal of Farm Economics* 37 (November 1955): 664–75.

13. It is not statistically acceptable to use the same data to determine both the length of the distributed lag and estimates of the coefficients. See George G. Judge, William E. Griffiths, R. Carter Hill, and Tsoung-Chao Lee, *The Theory and Practice of Econometrics* (New York: John Wiley and Sons, 1980), 648.

research literature is vague occasionally. For example, sometimes for unexplained reasons, a production function is used without an intercept. This imposes some peculiar restraints on the production function that one would not expect unless convincing justification were provided.[14]

Another methodical quirk in this literature is the choice of means when evaluating elasticities. Sometimes the arithmetic mean (simple average) is used; other times the geometric mean (the geometric mean is the *n*th root of the product of *n* values) is employed. The reasons for the choice are not discussed. Using arithmetic means has some intuitive appeal and, thus, explanation could be passed over; but using geometric means without justification is puzzling. One possible explanation is that a geometric mean is close to the arithmetic mean when there is not a lot of variability in the data while arithmetic means can be distorted by outliers. For example, among states there is wide variability in the magnitude of agricultural output, so a case could be made for using the geometric mean.

Another common practice in the literature is adjusting the marginal products for the lack of accounting for private agricultural research and extension.[15] The adjustment is often the presumed public research "share" of the total of public research, private research, and extension. There is no reason to assume *a priori* that public research, private research, and extension are completely interchangeable. The share adjustment assumes they are perfect substitutes. A second concern is that the models are misspecified by omitting theoretically relevant variables. Given the state of the available data, omitting the variables is understandable if not unavoidable. However, if the omitted variables are correlated with the included variables, the estimated coefficients are biased.[16] Therefore, adjusting the marginal product makes an assumption about the strength of the bias and its direction.

The existing empirical literature does indicate that there is a positive relationship between aggregate agricultural research expenditures and aggregate agricultural output. But given the wide range of the estimates of the IRR and the research coefficient and some of the methodological questions, one should be quite cautious in using any particular values.

Output effects of agricultural research in Texas

Most studies look at the internal rate of return to agricultural research. While perhaps useful in determining the investment potential of agricultural research, the IRR does not provide any information on the cumulative output effects in any one year that are due to all past research. This is because the IRR is, after all, a rate based on aggregate research expenditures and indicates nothing about the cumulative impact of research on output, given the likely growth in research funding.

To calculate the present output effects from past research spending and the future output effects from past, present, and future research expenditures, assumptions must be made about (1) the probable agricultural research funding profile, (2) the impact that any research funding level changes will have on output, and (3) how this impact will be distributed over time. Taking these assumptions in turn, Texas output will be affected by in-state, regional, and national research expenditures.

14. Consider a generalized Cobb-Douglas production function as used previously but without the constant term:

$$Q = K^a L^b.$$

In log-linear form,

$$\ln(Q) = a \ln(K) + b \ln(L).$$

When this model is estimated econometrically, the intercept term is forced to zero, meaning that zero units of output correspond, in this case, to zero inputs of capital and labor. This forces, *a priori*, the production surface through a particular point where one unit of capital, together with one unit of labor, produces one unit of output. (To get zero values with logarithms, the unlogged value must be 1.) Why should this be so? In addition, the constant term is considered an efficiency parameter, or a measure of the level of technology. Explicitly dropping it from the specification forces its implied value to equal 1. Without explanation it is difficult to accept these *a priori* restrictions.

15. The Cooperative Extension Service is the public means for conducting continuing education for farmers. Extension personnel provide the farmer with marketing information, new product information, and the demonstration of new techniques in farming. There is also an unknown amount of private extension carried on by agricultural input suppliers in promoting their products.

16. The bias is proportional to the coefficient vector of the omitted variables. See Judge and others, *Theory and Practice of Econometrics*, 411.

The Simple Mechanics of Research Effects on Output

The effects of research on output in 1983, for example, can be illustrated using the following methodology and hypothetical data. Assume the research coefficient is .07 and the lagged effect of research funding lasts for five years, with the weights .10, .20, .40, .20, and .10. Real research expenditures increase every year: 5, 6, 7, 8, and 9 percent for 1978 through 1982.

First, calculate the total percentage increase in output in response to an increase in real research funding in the years 1978–82. This effect is the percentage increase in research expenditures times the research coefficient and is shown in Table A. The total effect is then parceled out over the years according to the above lag scheme. This is shown in Table B.

Table C sets up a matrix of research years (the year the research expenditure increase occurred) and output effects in each of the affected years. (To each of the output effects 1 has been added so that the compounded effect can be calculated.) The last column, that for 1983, shows the total effect of all past research on current output.

The agricultural research funded in 1978–82 results in a 0.49-percent increase in agricultural output in 1983 solely due to research. If compounded, the output effect is 0.491 percent.

Table A
OUTPUT EFFECTS

1978 . . .	.05 × .07 = .0035
1979 . . .	.06 × .07 = .0042
1980 . . .	.07 × .07 = .0049
1981 . . .	.08 × .07 = .0056
1982 . . .	.09 × .07 = .0063

Table B
DISTRIBUTION OF OUTPUT EFFECTS

	.10	.20	.40	.20	.10
1978 . . .	.00035	.00070	.00140	.00070	.00035
1979 . . .	.00042	.00084	.00168	.00084	.00042
1980 . . .	.00049	.00098	.00196	.00098	.00049
1981 . . .	.00056	.00112	.00224	.00112	.00056
1982 . . .	.00063	.00126	.00252	.00126	.00063

Table C
CUMULATIVE OUTPUT EFFECTS

Research year	1979	1980	1981	1982	1983
1978 . . .	1.00035	1.00070	1.00140	1.00070	1.00035
1979 . . .	—	1.00042	1.00084	1.00168	1.00084
1980 . . .	—	—	1.00049	1.00098	1.00196
1981 . . .	—	—	—	1.00056	1.00112
1982 . . .	—	—	—	—	1.00063
				Sum . . .	5.00490
				Product . . .	1.00491

Forecasting a likely real expenditure path for agricultural research expenditures is fraught with uncertainty. The method selected for this study was to bracket the eventual expenditure profile by examining a range of growth rates for real research expenditures: 0, 3, 6, 10, and 20 percent a year.

The cumulative impact of any research funding changes on agricultural output is determined by the magnitude of the research coefficient—the output elasticity with respect to research. There are regional and national estimates of the research coefficient, but there is no estimate for Texas.

Estimating a meaningful research coefficient using the PF approach for Texas is very difficult, given the existing data resources. Data exist for some of the variables—agricultural output, a measure of capital, in-state, regional, and national research expenditures (not totally consistent because definitional changes make different years not strictly comparable)—but there is a problem in determining labor inputs. Ideally, a consistent series of labor hours used in Texas agriculture (including operator and operator family labor, full-time hired labor, and short-term or seasonal labor) is needed. Both published and unpublished farm labor data collected by the U.S. Department of Agriculture (USDA) are insufficient for these purposes, as are Census of Agriculture data.

Because there is no estimate of the research coefficient for Texas, it is assumed here that the coefficient is not dramatically different from regional and national estimates. Table 1 shows the range of the research coefficients, with most falling in the band of .02 to .15 for aggregate agriculture. To account for the influence of outside agricultural research and to avoid picking an "appropriate" value, a large band of possible Texas research coefficients was selected: .03, .07, .10, and .20.

A final assumption concerns the distribution of the impact of research spending on agricultural output. A fixed set of weights is assumed here using a scheme that specifies rising weights, two constant weights, and falling weights over 12 years, with the sum of the weights equaling unity. A period of 12 years was selected because many of the lag lengths used for empirical work are in the range of 11 to 13 years.[17] Here, in contrast to the econometric studies, the choice of a lag scheme is not as critical. The actual year-to-year percentage changes in real expenditures do vary significantly. Consequently, the impact on research in future years varies as well. According to the model used here, the output effect in any future year is the cumulative effect of the previous 12 years of changes in research funding. Thus, as output effects are forecast for years further in the future, the changes in research expenditures for future years have to be assumed. These changes are assumed to be constant; as a result, the more the forecast consists of assumed constant changes in research funding, the less sensitive are the cumulative output effects to the choice of lag structure.

To calculate the output effects in a given year of research spending in all previous years involves manipulating percentage changes in research expenditures, the research coefficient, and the lag scheme. (For details see the accompanying box.) This procedure was used for each combination of real research expenditure growth and research coefficient.[18]

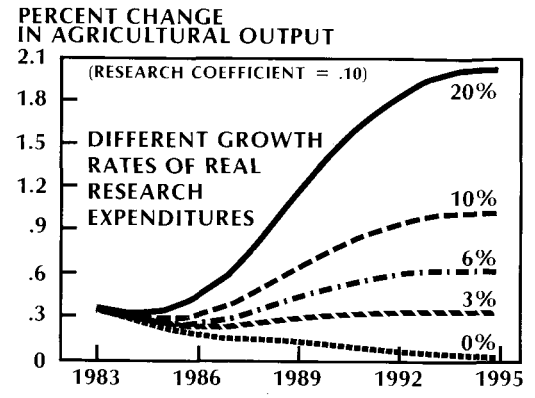
The results for the effects of Texas research funding on Texas output are presented in Table 2, which shows all the cases examined, and Chart 3, which portrays a typical research coefficient combined with different increases in research spending growth. In the "worst case" scenario in Table 2, that with a research coefficient of .03 and no growth in real research expenditures for the next 10 years, the output boost from Texas research starts out small and steadily declines, as one might expect. The "best case," with a research coefficient of .20 and a 20-percent growth rate in real research expenditures, shows modest effects on output in the early years

17. This scheme is described in George W. Norton, "The Productivity and Allocation of Research: U.S. Agricultural Experiment Stations, Revisited," in *Evaluation of Agricultural Research*, 105–15.

18. The deflator used to adjust the research expenditures for these calculations was different from the one used to plot Chart 2. The reason is that the new deflator more accurately reflects Texas conditions but is not available over the entire 1949–82 period. For the 1970's and 1980's, average salary increases for associate professors at Texas A&M University were used to deflate the labor component of research expenditures (source: *AAUP Bulletin* and *Academe* yearly salary survey). In addition, data for public expenditures on agricultural research for one other school were added to the expenditures series used (source: *Inventory of Agricultural Research*, vol. 2, various years). These data are not available for the entire 1949–82 period.

Chart 3

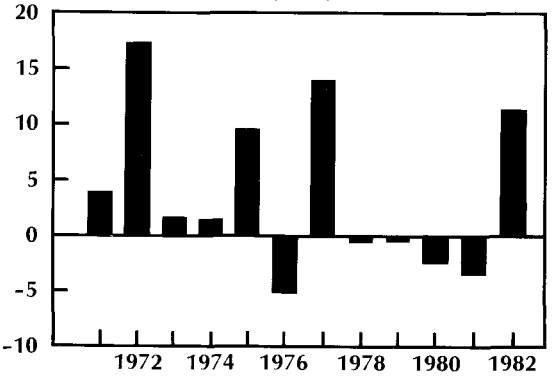
Texas Research Effects on Agricultural Output



SOURCE OF PRIMARY DATA: U.S. Department of Agriculture.

Chart 4

Texas Agricultural Research Expenditures



SOURCES: See footnotes 4 and 18.

but very sizable output increases of over 4 percent a year by the early 1990's. At this rate of increase, Texas agricultural output would double in less than 20 years. The different rates of spending growth for an in-between value of the research coefficient (.10) in Chart 3 show that increased Texas research funding does have a noticeable impact on output but only at very high growth rates.

The effect of in-state plus outside research on Texas agricultural output, while not explicitly modeled, is easily derived. Summing the spillover and inside research coefficients from Table 1 for the southern states gives a value of .135. That research coefficient is amply bracketed in Table 2 by .07 and .20. So with an optimistic real research growth of 6 percent at the state, regional, and national levels, one could expect between 0.6 and 1.2 percent of yearly growth in Texas output. Because the inclusion of outside research has only a small effect on Texas agricultural output and there is no guarantee that future outside research will meaningfully address the state's agricultural problems, only the impact of Texas research will be considered.

Feasibility of increasing output through research

Can Texas real research expenditures be increased, or can the size of the Texas research coefficient be enlarged? One cannot be sanguine about the prospects for large increases in research budgets. (See Chart 4.) During the 1970's, a reasonably prosperous period, real research appropriations increased 4 percent a year on average but actually declined for several years in the late 1970's. It is not likely that agricultural research, with a lack of immediacy given its relatively long-term impact, will compete effectively for additional public tax dollars during a period of tight state and national budgetary constraints.

If large real research funding increases are unlikely, the alternative is to try to boost the research coefficient, raising the productivity of agriculture by raising the productivity of agricultural research. There are two nonmutually exclusive approaches to raising the productivity of research.

The first approach is to work within the present system, with the USDA and the state agricultural experiment stations carrying on the bulk of publicly sponsored agricultural research. At the state level, several avenues are open for working within this system. One possibility is to change the mix of

Table 2
RESPONSE OF TEXAS AGRICULTURAL OUTPUT TO AGRICULTURAL RESEARCH

Research coefficient	Funding growth (Percent)	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
		Increase in output resulting from research (Percent)												
.03	.00	.11	.09	.07	.05	.04	.04	.04	.03	.02	.02	.01	.01	.00
.03	.03	.11	.09	.07	.07	.07	.08	.09	.09	.09	.10	.10	.09	.09
.03	.06	.11	.09	.08	.07	.08	.11	.13	.15	.16	.18	.18	.18	.18
.03	.10	.11	.09	.08	.09	.11	.15	.19	.22	.26	.28	.30	.30	.30
.03	.20	.11	.10	.10	.13	.18	.25	.34	.42	.49	.55	.58	.60	.60
.07	.00	.25	.20	.15	.12	.10	.10	.09	.07	.06	.04	.03	.01	.00
.07	.03	.25	.21	.17	.15	.15	.18	.20	.21	.22	.23	.23	.22	.21
.07	.06	.25	.21	.17	.17	.19	.25	.30	.34	.38	.41	.43	.43	.42
.07	.10	.25	.21	.19	.21	.26	.34	.44	.52	.60	.66	.69	.70	.70
.07	.20	.25	.22	.23	.30	.41	.59	.79	.98	1.15	1.28	1.36	1.40	1.41
.10	.00	.35	.29	.22	.17	.14	.14	.13	.09	.08	.06	.04	.02	.00
.10	.03	.36	.30	.24	.22	.22	.25	.28	.29	.31	.33	.33	.31	.30
.10	.06	.35	.30	.25	.25	.28	.35	.43	.49	.55	.59	.61	.61	.60
.10	.10	.35	.30	.27	.30	.37	.49	.63	.75	.86	.94	.99	1.01	1.00
.10	.20	.35	.32	.33	.42	.59	.84	1.13	1.41	1.65	1.83	1.95	2.01	2.02
.20	.00	.70	.58	.43	.35	.29	.29	.26	.19	.16	.13	.09	.03	.00
.20	.03	.72	.60	.48	.44	.43	.51	.57	.59	.63	.65	.66	.63	.60
.20	.06	.70	.59	.50	.50	.55	.71	.86	.98	1.10	1.18	1.23	1.22	1.21
.20	.10	.70	.60	.54	.60	.73	.99	1.26	1.50	1.73	1.89	1.99	2.02	2.02
.20	.20	.70	.63	.66	.85	1.18	1.69	2.28	2.83	3.32	3.69	3.93	4.05	4.07

"agricultural" versus "nonagricultural" research—for example, more hard research on agricultural commodities, less soft research on people as individuals. A second possibility is to change the mix within agricultural research to focus on the big-ticket agricultural commodities; for example, one possibility would be more research on livestock and less on fruits, vegetables, and nuts. Another avenue is to raise the quality of existing and proposed research. Finally, the time horizon for research could be changed toward a better mix of short-, medium-, and long-term research projects rather than mostly short-run topical research.

Alternating the mix of agricultural and nonagricultural commodity research, favoring the former, may not really save much and may cost dearly. The major noncommodity category, that which covers basic resources, consumed about 21 percent of the TAES budget in 1980.[19] This research—covering, among other things, soil, water, climate, recreation, wildlife and fish, and farm labor—is either necessary to continued agricultural productivity or popular with the public. The programs out of which resources might safely be transferred are too small to make much difference on their own.

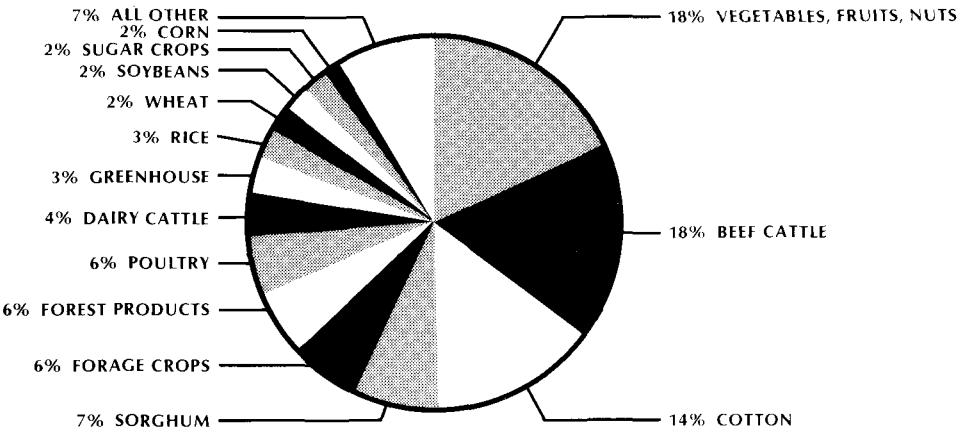
Another possibility is to shift resources within the agricultural commodity groupings. This would concentrate research efforts in areas that are most important for Texas in terms of agricultural cash receipts. Chart 5 compares the percentage breakdown of agricultural research at TAES to the percentage breakdown of agricultural cash receipts.[20] The most obvious disparity is that cattle

19. *Inventory of Agricultural Research, FY 1980.*

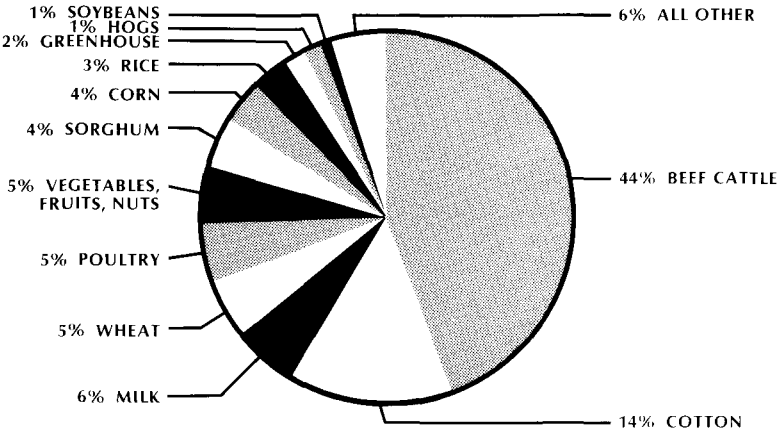
20. Only research expenditures for clearly identified commodity groups are utilized. Therefore, the sum of all commodity group expenditures does not equal total research expenditures.

Chart 5

Texas Agricultural Commodity Research, 1980



Texas Agricultural Cash Receipts, 1980



NOTE: The sum of all commodity group expenditures does not equal total research expenditures (see footnote 20).
SOURCE OF PRIMARY DATA: U.S. Department of Agriculture.

and calves made up 44 percent of gross cash receipts in 1980 while only 18 percent of the research money was so directed. On the other hand, vegetables, fruits, and nuts provided only 5 percent of gross cash receipts but took over 18 percent of the research budget.

There is an intuitive appeal to apportioning the research budget on the basis of the importance of the product to Texas agriculture. This has not been done already for several reasons: (1) there is no constituency effective enough (because it lacks either the interest or the political power) to increase its share of the research pie; (2) there is historical institutional inertia regarding which group gets what percentage; (3) with bottom-up research proposal generation, the research projects tend to fit the resources rather than vice versa; and (4) resources within the TAES are not perfectly substitutable in the short run.

Increasing the quality of the research is an obvious way to raise the effectiveness of research on output, but quality in research is a slippery concept to measure. There are numerous ways to try to measure the quality of a piece of published research—the number of times it was cited by other articles, for instance, or peer review, which is preferred by the National Academy of Sciences. But not all high-quality research is published, and some research that seems unimportant, tangential, or low in interest may prove to be quite significant in the long run. Given the difficulty in measuring true quality, it is hard to imagine that large productivity advances in performing agricultural research will come from attempts to increase the quality of research.

With the traditional methods of research agenda determination—particularly that of interaction between the experiment station and the agricultural interest groups—the research tends to be of a short-run nature, concerned with today's problems rather than what might be looming on the horizon. A more effective approach would be to have a balanced mix of short-, medium-, and long-term research projects, both in the basic sciences and in the applied area. Such a mix prevents premature exhaustion of applied research working on a basic research foundation. In addition, medium- and long-term research provides agricultural alternatives to deal with events that clearly lie in Texas' future, for example, the drawdown of the Ogallala aquifer, which will affect irrigated agriculture in the Panhandle. However, there is no real constituency for large changes in the research mix. Those whose relative, if not absolute, shares of short-term research would diminish would likely apply their political clout to good advantage.

The second approach to raising research productivity would be to move outside the present system. At the national level, several actions could be taken. One possibility is to abolish formula funds and greatly increase centralized direction of research, with competitive bidding for research grants in well-specified areas.[21] A second avenue is to promote the increased use of voluntary checkoffs to pay for research deemed essential to the sponsoring commodity groups while the public funding of research is cut back.[22] A third, but highly unlikely, suggestion is to back out of public agricultural research altogether. This implies that the free market will provide all the research that seems to have profit potential. At the state level, since most of the funding for public agricultural research is from the state, such actions would have little direct effect in the short or medium term other than greatly reducing regional and bilateral state cooperation in research projects.

Radical change, such as would be necessary for all proposals that would supplant the traditional public agricultural research system, is remote. There is not a public sense of urgency about the problems agricultural research could tackle. Without those feelings of urgency, it is difficult to rally sufficient political support to implement the far-reaching changes.

Conclusions

Can Texas agricultural output be efficiently increased by agricultural research? This article has focused on two main determinants of the future impact of current agricultural research on output. One is the size of the increases in spending for agri-

21. Formula funds are federal funds for agricultural research that are distributed directly to the states according to various criteria. The Federal Government has little say in how these funds are used as long as the use falls within certain regulations and approved projects.

22. A checkoff system allows the individual farmer to contribute part of his cash receipts for activities to promote his particular commodity.

cultural research (as a proxy for research effort). The second determinant is the influence of research on output, measured by the research coefficient (the elasticity of output with respect to research). Even with a 6-percent increase in real spending per year and an optimistic research coefficient of .10, output would grow at not much more than 0.6 percent a year. Including generous estimates of the influence of outside-the-state research would boost the impact of research on Texas output growth to 1.2 percent a year. It would take more than 60 years for this latter rate to double Texas agricultural output through research alone.

Is it likely that the growth in expenditures for agricultural research will increase greatly in Texas? In percentage terms the state spends a minuscule amount on agricultural research. In 1982, Texas provided nearly $40 million for agricultural research out of a budget of over $12 billion, or less than 0.4 percent.[23] But agricultural research has low public visibility, and the problem that it attacks, that of low or no agricultural productivity growth, is a gradual and long-term one. With this lack of immediacy, there is unlikely to be a general clamor for greatly increased funding in this time of both state and federal budget austerity.

23. Sources: *Inventory of Agricultural Research, FY 1982*, and the Comptroller of Public Accounts for the state of Texas.

If large increases in funding agricultural research are not likely, can the existing research expenditures be used more efficiently, thus getting more research for each dollar? The traditional methods of determining the research agenda are securely in place and resist easy modification. In addition, there is no natural constituency advocating such institutional changes, so they have little chance of being adopted.

Without change in the funding growth or the research coefficient, one must depend on the private sector for the needed advances in technology or hope for some kind of dramatic breakthrough in research. In this situation, the free market determines which area of the country will be able to compete successfully in which agricultural products.

In the final analysis, it must be the public that decides whether there will be a greatly increased emphasis on agricultural research to boost agricultural productivity in Texas and thereby maintain or improve the state's competitive position in agricultural markets. But unless there is a significant change in the public's perception of the need for agricultural research, reflected in significantly higher increases in real dollars for research or support for different institutional practices, then the likelihood of substantive gains in agricultural output through public agricultural research is small.

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