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Federal Resewe Membership and the Role of Nonmember Bank Resewe Requirements

By Carl M. Gambs

Recent withdrawals of a large number of banks from the Federal Reserve System have focused attention on the importance of the reserve requirements imposed by the Federal Reserve on member banks.[1] Since withdrawal of a bank from the Federal Reserve System automatically makes it subject to state reserve requirements, these requirements are also important in determining whether banks choose to belong to the Federal Reserve System. Nonmember banks in all states but Illinois are subject to reserve requirements. However, state requirements are generally lower than those set by the Federal Reserve and allow nonmember banks to hold reserve balances in interest-earning securities or in service-earning deposits with correspondent banks.

This article examines the role of reserve requirements on both Federal Reserve member and nonmember bank deposits, with particular attention to the Tenth Federal Reserve District.[2] The first section considers the purpose and importance of reserve requirements in general. The next section compares the level of member bank reserve requirements to the level of nonmember reserve requirements in the Tenth District states. Finally, evidence is examined on the extent that state reserve requirements affect the cash reserve holdings of nonmember banks.

PURPOSE AND IMPORTANCE OF RESERVE REQUIREMENTS

Three different roles for reserve requirements have been suggested. One role of reserve requirements, it originally was thought, is to help ensure the liquidity and safety of banks. Another role, it is contended, is that requirements serve as a tax on banks. However, contemporary analysts generally emphasize the role that reserve requirements play in facilitating monetary control.

1 At least 41 member banks have left the System in every year since 1968. In 1977, 69 banks withdrew, the second highest number on record, and 37 banks left in the first half of 1978. Furthermore, while earlier withdrawals were almost entirely by very small banks, 15 of the banks withdrawing in 1977 had deposits of more than $100 million. See Board of Governors of the Federal Reserve System, "The Burden of Federal Reserve Membership, NOW Accounts, and the Payment of Interest on Reserves," June 1977; Robert E. Knight, "Comparative Burdens of Federal Reserve Member and Nonmember Banks," Monthly *Review,* Federal Reserve Bank of Kansas City, March 1977, pp. 3-28; and Peter S. Rose, "Banker Attitudes Toward the Federal Reserve System: Survey Results," Journal of Bank *Research,* 8 (Summer 1977), pp. 77-84.

2 The Tenth District includes Colorado, Kansas, Nebraska, Wyoming, most of Oklahoma, northern New Mexico, and 43 counties in western Missouri.

Reserve Requirements to Ensure Bank Liquidity and Safety

Historically, the introduction of reserve requirements was motivated by the belief that a bank's required reserves would provide liquidity in the event of an unexpected ouflow of deposits .and would protect depositors in the event of the insolvency of the bank.' However, under the fractional reserve systems used by both the Federal Reserve and the states, required reserves do not contribute much to liquidity and safety. Suppose, for example, that a state imposed a 10 per cent reserve requirement on demand deposits. A $10 deposit outflow would reduce a bank's cash assets by $10, but only $1 would come from required reserves. Thus, most of the liquidity to meet the ouflow must come from other sources.'

Early proponents of reserve requirements also believed that required reserves would provide protection to depositors in the event of insolvency. This belief confuses the role of capital—which allows liabilities to be met in the event of a decline in asset values—and that of reserves, which are simply one type of asset. For example, the only default protection provided by a 10 per cent reserve requirement is a guarantee that the institution will have on hand $1 for every $10 of deposits. Only if required cash reserves were equal to 100 per cent of deposits would they protect depositors.

Thus, cash reserve requirements do not contribute much to bank liquidity or to the protection of depositors. Moreover, to the very limited extent that required reserves serve these functions, reserves could be held in the form of liquid interest-bearing assets, so that cash requirements would be unnecessary.[5]

Reserve Requirements as a "Tax" on Banks

A further role of reserve requirements, it is contended, is that they serve as a tax on banks. To the extent that member banks hold higher levels of noninterest-bearing reserve assets than they otherwise would, reserve requirements on member banks are effectively a tax on these banks that provides revenue to the Federal Government.[6] The tax on banks is equal to the interest that would otherwise have been earned on reserve assets. The Government revenue arises from the interest earned by the Federal Reserve on securities acquired to support member bank reserves. Suppose, for example, the Federal Reserve increased bank reserve requirements but did not want to induce a change in the money supply. In this case, the System would purchase securities in the open

3 For a discussion of pre-Civil War state reserve requirements, see Bray Hammond, "Banking Before the Civil War," pp. 1-14, in Deane Carson, ed., *Banking and Monetary Studies* (Homewood, Ill.: Irwin, 1963).

4 Required reserves do provide liquidity for very brief periods. The Federal Reserve and most states use a system of averaging reserves and deposits over a period of one or more weeks. Under this system, reserves can be used as a source of liquidity for a very brief period of time, as long as the reserve requirements are met on average over the period.

5 The fact that required reserves do not serve as a source of liquidity in the event of a deposit ouflow has been widely recognized at least since the beginning of this century. Nevertheless, a survey of state banking commissioners in 1952 yielded the near unanimous view that the primary function of reserve requirements was to serve as a source of liquidity. Joint Committee on the Economic Report, 82d Cong., 2d Sess., ***Monetary Policy and the Management of the Public Debt, Replies to Questions and Other Material for the Use of the Subcommittee on General Credit Control and Debt Management*** (Washington: Government Printing Office, 1952), pp. 978-83.

6 There is an old controversy as to whether the Federal Reserve earns interest on funds deposited with it by member banks, or earns interest on funds created by its own open market operations. The answer is clearly both, with the controversy being akin to a discussion of which side of a pair of scissors cuts.

market to provide enough new reserves to support an unchanged level of deposits. To meet the higher requirements, member banks would reduce their interest-earning assets and build up their noninterest-earning reserve assets.[7] The final result would be higher earnings for the Federal Reserve and lower earnings for commercial banks. Since Federal Reserve profits are remitted to the U.S. Treasury, the impact of higher reserve requirements amounts to increasing taxes on member banks.

These "taxes" apply only to member banks. Reserve requirements applied to nonmember banks by the various states provide no revenue to state treasuries or to the Federal Government, with the minor exception of a few states that require some fraction of reserves to be held in vault cash.[8] While state reserve requirements do not generate "tax" revenues, they may still be burdensome to nonmember banks to the extent that banks hold more reserves than would otherwise be the case. However, because many of the reserve assets held by nonmember banks provide a return either in interest income or in services, the burden is generally less for nonmember banks than for member banks with the same level of reserve requirements.

Reserve Requirements as a Monetary Policy Tool

The primary purpose of reserve requirements imposed on member banks by the Federal Reserve is to facilitate monetary control. Because member banks must hold reserves behind deposits, the total quantity of deposits that can be issued is limited by the supply of reserves in the banking system. Thus, the Federal Reserve can influence the quantity of deposits and the money supply by changing the quantity of reserves, normally through open market operations.[9]

The Federal Reserve can also influence the money supply by changing the level of reserve requirements. For example, an increase in reserve requirements will lead to a reduction in the total volume of deposits, unless the total quantity of reserves is simultaneously increased. The reduction in deposits would occur because the reserves available in the banking system would not be sufficient to support the existing level of deposits, and banks would need to contract their size until the reserve deficiency was eliminated.[10]

Some observers argue that reserve requirements are not important for monetary policy because they are infrequently changed. However, the frequency with which reserve requirements are changed is not important for determining whether requirements facilitate monetary control. Requirements facilitate control if they make the relationship between the level of deposits and the level of bank reserves more predictable than it would be in the absence of reserve requirements. However, if banks would hold predictable quantities of reserves in the absence of reserve requirements,

[7] For a discussion of reserve requirements as taxes, see William G. Dewald, "Linking Required Reserves Reform to the Correspondent Banking System," in *Proceedings of a Conference on Bank Structure and Competition,* Federal Reserve Bank of Chicago, April 27-28, 1978.

[8] The essential difference between member and nonmember banks here is that member banks hold liabilities of the Federal Reserve which, in turn, holds interest-earning assets and turns the earnings over to the U.S. Treasury. Vault cash is the only Federal Reserve liability held by nonmembers.

[9] J. A. Cacy, "Reserve Requirements and Monetary Control," *Monthly Review,* Federal Reserve Bank of Kansas City (May 1976), pp. 3-13.

[10] Assuming that banks were not holding large amounts of excess reserves—that is, reserves greater than needed to meet requirements—prior to the increase in reserve requirements.

required reserves would not be necessary for monetary control.[11]

The use of reserve requirements as a monetary control device applies only to member banks. Reserve requirements of nonmember banks do not serve a direct monetary control function because in general state requirements can be met by holding assets that are not under the direct control of the Federal Reserve—such as balances at other banks and Government securities.

Role of State Reserve Requirements

Of the three listed purposes of reserve requirements, two do not apply to state reserve requirements, i.e., their use for monetary control and their use as a bank tax. The third purpose—a source of liquidity and safety—is of minor importance. Thus, it might be argued that state reserve requirements have virtually no function.

However, state reserve requirements may indirectly play a role in facilitating monetary control. If state requirements encourage membership in the System, they strengthen monetary control because more members mean more deposits directly subject to Federal Reserve control. The extent to which state requirements encourage membership depends importantly on two factors. One is the level of nonmember bank reserve requirements relative to member requirements. The other is the extent that these requirements are effective that is, whether or not they actually induce banks to hold a higher level of cash assets than would otherwise be the case. The remainder of this article will look at the level of nonmember reserve requirements in Tenth District states and examine the evidence on the effectiveness of state reserve requirements.

FEDERAL RESERVE AND TENTH DISTRICT RESERVE REQUIREMENTS: 1962-78

Both Federal Reserve and state cash reserve requirements have been lowered in recent years. State requirements, however, have been lowered more than System requirements. The relatively greater decline in state requirements has pushed them below those imposed by the Federal Reserve and has reduced the extent that state requirements serve the function of encouraging banks to become and remain members of the Federal Reserve System.

The level of state cash reserve requirements in the Tenth Federal Reserve District is shown in Table 1.[12] In Colorado, there are no cash reserve requirements, as all of the required reserves can be held in the form of securities. In Missouri, Nebraska, and New Mexico, the provision in state law that allows one-half of required reserves to be met with securities reduces state cash reserve requirements to levels somewhat below the requirements for member banks. In Kansas and Oklahoma, reserve requirements are approximately the same for member and nonmember banks. In Wyoming, state reserve requirements tend to be somewhat higher than the requirements for Federal Reserve members, especially for very small banks, due to the relatively high reserve requirements on time and savings deposits and on the fust $10 million of demand deposits. As

11 Reserve requirements may also be unnecessary if the Federal Reserve relies on interest rates rather than bank reserves to control the money stock. See J. A. Cacy, "The Impact on Monetary Control of Reducing Reserve Requirements," Working Paper, Federal Reserve Bank of Kansas City (forthcoming).

12 For reserve requirements in all 50 states, see R. Alton Gilbert and Jean M. Lovati, "Bank Reserve Requirements and Their Enforcement: A Comparison Across States," ***Review,*** **Federal Reserve Bank of St. Louis, March 1978, pp. 22-32.**

a result, Wyoming has the highest proportion of member banks (75 per cent as of December 31, 1977) in the nation.

The availability of a wide array of services in return for balances on deposit with correspondents increases the relative disadvantage of member banks in most Tenth District states. Furthermore, nonmember banks are relatively better off because they are frequently given immediate credit for transit checks deposited with correspondents, while the Federal Reserve delays granting credit for checks for up to two days, depending on the location of the bank on which the check is drawn.[13]

The generally lower level of cash reserve requirements for nonmember banks is a development of the past 15 years. (See Chart 1.) Reserve holdings have declined relative to assets for both member and nonmember banks. Holdings have dropped because reserve requirements have been reduced and because time deposits, which have lower reserve requirements than do demand deposits, have become a more important source of bank funds.[14] However, the decline has been somewhat larger for nonmember than for member banks. The greater decline for nonmember banks is not due to a relatively greater increase in the importance of time and savings deposits for nonmembers; it is due instead to a larger reduction in reserve requirements for nonmembers than for members.[15] Table 2 illustrates the greater decline for nonmembers by showing the level of cash reserve requirements levied against the demand deposits of a hypothetical bank with exactly $25 million in demand deposits in 1962 and in 1978. As can be seen, state reserve requirements declined sharply in many of the Tenth District states between 1962 and 1978. These declines result largely because states now allow banks to use Government securities to meet reserve requirements to a greater extent than in 1962.

The smaller reduction in member bank reserve requirements has contributed heavily to the decline in the share of Tenth District banks holding membership in the Federal Reserve System from 42.3 per cent in 1962 to 36.3 per cent in 1978. Similarly, the share of total Tenth District bank deposits held in member banks declined from 74.9 per cent in 1%2 to 63.3 per cent in 1978. Additionally, the increase in interest rates over this period has meant that the cost of holding noninterest-bearing reserve balances at the Federal Reserve has increased.[16]

DO STATE RESERVE REQUIREMENTS MATTER?

Some observers have argued that state reserve requirements are so low that they are not effective in inducing banks to hold more

13 Although banks are given immediate credit for checks deposited, the account analysis performed by the correspondent will give credit only for collected balances. Robert E. Knight, "Account Analysis in Correspondent Banking," Monthly *Review.* Federal Reserve Bank of Kansas City, March 1976, pp. 11-20.

14 It has been estimated that between February 1968 and February 1977, 55.6 per cent of the decline in the ratio of required reserves to deposits at member banks was due to changes in reserve requirements and the remainder to changes in the deposit structure. Thomas D. Simpson, "The Behavior of Member Bank Required Reserve Ratios and the Effects of Board Action, 1968-77," Staff Paper No. 97 (Washington, D.C.: Board of Governors of the Federal Reserve System, July 1978), p. 20.

15 The decline in the importance of demand deposits was similar at both Tenth District member and nonmember banks over this period. Demand deposits dropped from 72.6 per cent of member bank deposits in 1962 to 42.5 per cent in 1976. At nonmember banks, demand deposits dropped from 66.3 per cent of total deposits in 1962 to 37.1 per cent in 1976.

16 See Carl M. Gambs and Robert H. Rasche, "Costs of Reserves and the Relative Size of Member and Nonmember Bank Demand Deposits," *Journal* of Monetary Economics, 4 (November 1978), pp. 715-33, for estimates of the relative importance of differential Federal Reserve and state reserve requirements and of increasing interest rates for the decline in Federal Reserve membership.

Table 1
RESERVE REQUIREMENTS
June 30,1978

State	Deposits Subject to Reserve Requirements	Current Reserve Requirement Ratios	Assets Eligible to Meet Requirements: Vault Cash	Demand Balances Due From Banks	Securities	Other
Federal Reserve	T Dem–CIPC–Due From	7% first $2 million, plus 9X% $2–$10 million, plus 11%% $10–$100 million, plus 12¾% $100–$400 million, plus 16¼% over $400 million	X			FR Deposits
	S	3%	X			FR Deposits
	T maturing in 30-179 days	3% first $5 million, plus 6% over $5 million	X			FR Deposits
	T maturing in 180 days to 4 years	2½%[1]	X			FR Deposits
	T maturing in 4 years or more	1%[1]	X			FR Deposits
Colorado[2]	T Dep–US_d–SL_d–US_t–SL_t	15%	X	X[3]	X[4]	
Kansas[2]	T Dem–US_d–SL_d	FR	X	X		
	TS–US_t–SL_t	FR	X	X		
Missouri	T Dem	FR	at least 50% including local CIPC		up to 50%[5]	
	TS	3%				
Nebraska	T Dem	15%				
	TS	5%	at least 50%		up to 50%[6]	

Table 1
(Continued)

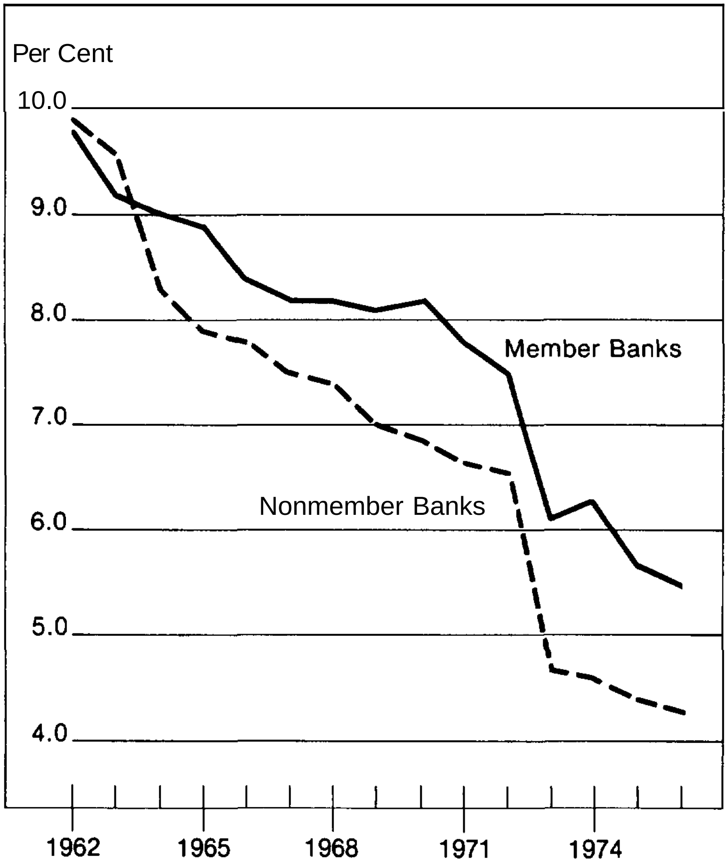
New Mexico	T Dem	12%	at least 50%		
	TS	4%	Including local CIPC[3]		up to 50%[7]
Oklahoma	T Dem	FR	X	X[3]	CIPC[8]
	TS	FR	X	X[3]	CIPC[8]
Wyoming[2]	T Dem$-US_d-SL_d$	20%			
	TS$-US_t-SL_t$	10%	at least 50%[3,9]		up to 50%[10]

1 The average of reserves on savings and other time deposits must be at least 3 per cent, the minimum specified by law.
2 Exemption applies only to public deposits which are secured by pledged securities.
3 Deposits at approved depository banks.
4 Unpledged, negotiable direct U.S. obligations.
5 Up to 50 per cent of required reserves may be invested in unpledged U.S. Government obligations maturing within five years and unpledged Federal funds sold to approved depositories.
6 Up to one-half of reserves can be met with unpledged U.S. Government securities, at market value, or obligations of the Commodity Credit Corporation, at face value.
7 Direct U.S. Government obligations maturing within 100 days.
8 CIPC which have been received by approved depository banks.
9 Includes CIPC.
10 Unpledged U.S. Treasury Bills.

Abbreviations in Table 1

T Dem	Total demand deposits
CIPC	Cash items in the process of collection
Due From	Demand deposits due from domestic commercial banks
FR Deposits	Member bank demand deposits at Federal Reserve Banks
S	Savings deposits
T	Time deposits
T Dep	Total deposits
US	U.S. Government demand deposits
SL_d	State and local government demand deposits
US_d	U.S. Government time deposits
SL_t	State and local government time deposits
FR_t	Same as reserve requirements of the Federal Reserve

Chart 1
REQUIRED CASH RESERVES AS A PER CENT OF TOTAL ASSETS
(Tenth Federal Reserve District)



SOURCE: Derived from data for all Tenth District member banks and sample of nonmember banks. Individual state ratios were first computed and the District composite was then obtained by weighting by total deposits in each state. For a description of the sample of nonmember banks, see Carl M. Gambs, "State Reserve Requirements and Bank Cash Assets," Research Working Paper 78-05, Federal Reserve Bank of Kansas City, August 1978, pp. 10-11.

cash assets than they would hold if they were not subject to reserve requirements. State reserve requirements can be said to be effective if a change in the level of required cash reserves leads to a change in the level of actual cash reserves. If a $1 increase in required reserves leads to a $1 increase in actual cash reserves, the reserve requirement is **fully effective.** If the $1 increase in required reserves leads to an increase in actual reserves by some amount less than $1, the reserve requirement is partly **effective.** If state requirements are effective they provide some encouragement for banks to become or remain members of the Federal Reserve System. Moreover, the greater the degree of effectiveness, the more likely that

Table 2
REQUIRED CASH RESERVES AS A PER CENT OF DEMAND DEPOSITS (A Bank with $25 Million in Demand Deposits)

	1962	1978
Federal Reserve	12.0	10.6
State Nonmembers:		
Colorado	0.0	0.0
Kansas	12.5	10.6
Missouri	15.0	5.3
Nebraska	12.0	7.5
New Mexico	12.0	6.0
Oklahoma	15.0	10.6
Wyoming	20.0	10.0

banks will choose to be Federal Reserve members.

The effectiveness of state requirements also affects the extent to which the Federal Reserve can increase membership by lowering member bank reserve requirements. If state requirements are ineffective, the existence of the requirements does not cause banks to hold more reserves, nor does it place any burden on the banks subject to the requirements. In such a situation, if the Federal Reserve reduces requirements to reduce the relative burden of membership, the state banking authority could not make nonmember status more attractive correspondingly, as there would be no burden of state reserve requirements to reduce.

Empirical Evidence on the Effectiveness of Reserve Requirements[17]

Some researchers have examined the ratio of actual to required reserves to ascertain whether or not a state's reserve requirements are effective. If this ratio is well above 1.0, it is argued, state reserve requirements are not effective because banks are holding more reserves than required.[18] The logic is that if actual reserves are substantially greater than required reserves, the level of cash assets held must be determined by factors other than reserve requirements. Table 3 shows that for a sample of Tenth District nonmembers the ratios of actual to required reserves are generally well above 1.0. From these ratios alone, it might be inferred that state reserve requirements in the Tenth District are not effective. However, this inference is not necessarily valid. Many banks may want to hold excess reserves because they prefer to be highly liquid or because they want to ensure that an unexpected deposit oufflow will not leave them with reserves below the required level.

Furthermore, even though the average ratio may exceed 1.0, a substantial number of banks may have a ratio near 1.0.[19] Table 3 shows that a large portion of Tenth District banks have actual reserve ratios relatively close to 1.0, i.e., between 1.00 and 1.25. Reserve requirements may be effective for these banks, even if they are not for all of the banks in the sample. A mixture of some banks with partly or fully effective reserve requirements and others with ineffective reserve requirements would make

17 For a discussion of previous work on the effectiveness of reserve requirements, see Gambs, "State Reserve Requirements and Bank Cash Assets," pp. 3-8.

18 For an example of this approach, and for ratios similar to those in Table 3 for other states, see Board of Governors of the Federal Reserve System, "The Burden of Federal Reserve Membership, NOW Accounts, and the Payment of Interest on Reserves," Appendix A.

19 The existence of banks with a ratio of less than 1.0 does not necessarily mean that these banks were violating state reserve requirements. It may reflect the fact that these ratios were calculated using data for only one day, instead of over the entire reserve periods because data were not available to perform the latter computation.

Table 3
RATIO OF CASH ASSETS TO REQUIRED CASH RESERVES
(Per Cent of Banks in 1976)

Ratio	Kansas	Missouri	Nebraska	New Mexico	Oklahoma	Wyoming
<1.00	7.6	7.3	14.9	16.0	5.1	20.0
1.00–1.10	3.3	5.5	6.4	0.0	7.7	20.0
1.10-1.25	16.3	14.5	25.5	0.0	12.8	30.0
1.25-1.50	22.8	21.8	14.9	0.0	12.8	10.0
1.50-2.00	20.7	41.8	19.1	10.0	35.9	10.0
2.00-3.00	16.3	5.6	6.4	50.0	23.1	10.0
3.00-4.00	10.9	3.6	0.0	30.0	2.6	0.0
>4.00	2.2	0.0	0.0	0.0	0.0	0.0
Average	1.83	1.57	1.45	2.59	1.70	1.30

SOURCE: Calculated for a sample of 272 Tenth District banks. For a description of the sample, see Gambs, "State Reserve Requirements and Bank Cash Assets," pp. 10-11.

the ratio for all banks in a state appear to be partly effective.

The effectiveness of state reserve requirements in the Tenth District was also examined through the use of linear regression analysis.[20] The examination, which considered the cash holdings of 276 Tenth District nonmember banks over the 1962-76 period, concluded that state reserve requirements were partly effective. Over the period studied, a $1 increase in required reserves, on an average, led to a $0.39 increase in cash asset holdings. Bank cash holdings were also found to be affected by several variables other than reserve requirements. The variables include bank size, the ratio of demand deposits to total assets, and interest rates.[21]

The results of the above examination imply that state reserve requirements have an indirect role in facilitating monetary control. Banks are less likely to leave the Federal Reserve System when there are state reserve requirements than if there were none. If there were no state reserve requirements, there would be a much greater **reduction** in the burden of reserve requirements when banks changed from member to nonmember status than is now the case.

20 Gambs, "State Reserve Requirements and Bank Cash Assets."

21 The equation estimated by multiple regression analysis was:

$$VDF/TA = \underset{(1.19)}{0.0121} + \underset{(3.92)}{11.745}\ 1/TA + \underset{(8.09)}{0.393}\ CR/TA + \underset{(16.17)}{0.1583}\ DD/TA - \underset{(-3.68)}{0.0017}\ RTB + \sum_{i=5}^{276} a_i BD_i$$

$$\sum_{i=5}^{276} a_i = 0$$

$\bar{R}^2$ = ,626 D.W. = 1.86 n = 4080

Where:
- VDF = Vault cash and due from banks
- TA = Total assets
- CR = Required cash reserves
- DD = Total demand deposits
- RTB = The rate on 3-month Treasury bills
- BD_i = The i-th bank dummy variable

The numbers in parentheses are t values.

This finding has implications for the impact of changes in member bank reserve requirements on the burden of Federal Reserve membership. In brief, the burden depends on the degree that changes in member and nonmember bank reserve requirements induce the two types of banks to change their holdings of assets. For example, suppose reserve requirements for member and nonmember banks are reduced by the same amount. If member bank requirements are fully effective, but nonmember bank requirements are not effective, the relative burden of membership will be reduced, as there will be a reduction in the cash asset holdings of members, but not of nonmembers. On the other hand, if both member and nonmember reserve requirements are fully effective, equal reductions in reserve requirements will leave the relative burden of membership unchanged—that is, state regulators can completely offset the effect of the member bank reserve reduction on the desirability of membership. The results cited here suggest that nonmember requirements are partly effective, so simultaneous reductions in member and nonmember requirements would reduce the relative burden of member banks, but not by as much as if nonmember requirements were ineffective. Thus, state regulators could not offset the reduced burden of member banks unless they lowered their requirements more than did the Federal Reserve.

In those states where all or part of the reserve requirements can be met with interest-bearing assets, it would be particularly difficult for state regulators to offset Federal Reserve reductions of member bank reserve requirements. If, for example, a state's nonmember banks were allowed to meet one-half of their reserve requirements with interest-bearing assets, the state would have to lower its reserve requirements two percentage points for every one percentage point reduction in the Federal Reserve reserve requirement to get the same reduction in the level of cash requirements.

SUMMARY AND CONCLUSIONS

Federal Reserve and state reserve requirements serve very different purposes. Federal Reserve requirements are used for monetary control purposes and can also be viewed as a tax on member banks, but state requirements directly serve neither of these functions. State requirements do play an indirect role, in that they tend to make Federal Reserve membership more attractive than if states did not impose requirements. Neither Federal Reserve nor state reserve requirements play an important function in ensuring bank liquidity or safety, although state regulators may find the degree to which banks comply with requirements to be a useful guide to the general soundness of bank operations.

Federal Reserve requirements are much more burdensome than state requirements because they are higher and must be met with vault cash and deposits with Federal Reserve Banks, while state requirements can be met with deposits with correspondents (including uncollected funds in many cases) and in some cases with interest-bearing securities. While many banks hold more reserve assets than required to meet reserve requirements, evidence suggests that state reserve requirements, at least in the Tenth District, are partly effective. Thus, they are probably responsible for Federal Reserve membership being higher than it would be in the absence of state reserve requirements.

Energy Alternatives in U.S. Crop Production

By Kerry Webb and Marvin Duncan

A dramatic result of the 1973 Arab oil embargo and the quadrupling of imported oil prices has been a marked shift in the way U.S. citizens view their energy consumption. These events and subsequent OPEC price actions have brought into clear focus the importance of wise use of both domestic and imported energy sources. American farmers are particularly aware of the impact of higher prices and threatened supply shortages, despite the fact that agricultural production uses only 4 or 5 per cent of all energy consumed annually in the United States.[1] Agricultural producers function in a very competitive environment and find it difficult to pass along to consumers increases in production costs such as fuel price increases. Additionally, timely operations are increasingly important to farmers, which suggests that fuel supply shortfalls during critical periods, such as harvest time, could sharply reduce agricultural output.

This article discusses the opportunities farmers may have to substitute other inputs for energy in production. A mathematical model is used to assess the potential substitutability among agricultural inputs at both national and regional levels. Some policy implications of the empirical evidence are also discussed.

ENERGY DEPENDENCE

Ready access to low-cost energy has revolutionized the way Americans live. Nowhere has this revolution been more pronounced than in agriculture, where the sizable increase in output during the last 70 years is due largely to the increased use of energy on the farm. Farmers' access to abundant low-cost chemical and mechanical energy supplies has been the key factor in the development of today's highly sophisticated agricultural production methods. U.S. farmers are currently using over 4.4 million tractors, 3 million trucks, and 500,000 combines. More than 35 million acres are being irrigated using pump systems. Over 20 million tons of fertilizer and 400,000 tons of pesticides are being used annually by the nation's farmers. All of these items require energy in some form-either as a fuel for operation or as a primary ingredient for its manufacture. As a result, energy has become a basic raw material in agricultural production.

Throughout this century, agriculture's demand for energy has always been satisfied. Even during periods of war, farmers have

[1] Marvin Duncan and Kerry Webb, "Energy and American Agriculture," *Economic Review*, Federal Reserve Bank of Kansas City, April 1978.

received special consideration for their energy requirements. Moreover, energy—and particularly petroleum-derived fuels—has been priced so that it has been profitable for farmers to use increasing amounts in their production. Indeed, for most of this century, the price of energy relative to many other inputs has been decreasing.

ENERGY SHORTAGE

In spite of recent legislative movements to shore up the U.S. energy program, the United States still faces a rather delicate supply situation. The winters of 1976 and 1977 showed how uncertain the supply of natural gas has become. The coal strike of 1978 could have had disastrous results if it had lasted much longer. Moreover, recent international events highlight the uncertain status of foreign oil supplies. Domestic strife in Iran has temporarily disrupted oil production in that country. OPEC crude oil price increases of 14.5 per cent during 1979 will add measurably to U.S. trade deficit problems and price inflation. Thus, dependendence upon foreign energy supplies creates the potential for economic hardship and a high degree of uncertainty regarding energy availability.

Agriculture can be affected by energy supply disruptions just as can every other sector in the economy. For example, petroleum products refined from crude oil provide over 75 per cent of the direct on farm energy used in crop production. In 1977, 45 per cent of the crude oil going to U.S. refineries was imported and roughly 75 per cent of the imported oil came from OPEC nations.. Thus, about one-third of the direct energy used on U.S. farms comes from foreign lands and about one-fourth comes from the OPEC countries.

Although agriculture does have high priority in times of fuel rationing, political developments or other disruptions in some of these countries could have very damaging effects upon agricultural production—at least during limited time periods. This fact has been emphasized by U.S. Secretary of Agriculture Bob Bergland:

> The biological nature of agriculture is such that operations must be performed during rather critical time periods, or serious losses in production can occur. The delay of a few hours in energy supplies could mean death for poultry in environmentally controlled housing. For other operations such as corn planting, the delay of planting by a week can reduce yields per acre by 7 to 14 bushels. In wheat harvest, the delay of a few days for combine fuel can reduce a crop from 50 bushels per acre to 5, depending on the weather.'

In addition to supply shortages, rising energy prices may also mean that farmers will need to find ways to conserve the energy that is available and to substitute other inputs for energy. From 1972 to 1977, average prices paid by farmers for fuel and energy increased 87 per cent. Table 1 shows the prices that farmers have paid for various fuels, both commonly measured and when all fuels are converted to an equivalent energy unit of 1 million Btu. In the future, increasing demand from other sectors of the economy, the deregulation of natural gas and oil prices, and the reduction in petroleum reserves is likely to continue to put upward pressure on energy prices.

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[2] Bob Bergland, Secretary of Agriculture, Statement before the Subcommittee on Rural Development, Senate Committee on Agriculture, Nutrition and Forestry, July 26, 1978.

Table 1
AVERAGE ANNUAL PRICES PAID BY FARMERS FOR VARIOUS FUELS

Year	Gasoline ($/gal.)	Diesel ($/gal.)	L.P. ($/gal.)	Natural Gas' ($/1000 c.f.)	Electricity† (¢/Kwh)
	Common Measurement				
1972	.310	.190	.156	.473	2.23
1973	.337	.226	.169	.525	2.31
1974	.465	.365	.302	.693	2.66
1975	.498	.391	.304	1.040	3.07
1976	.532	.413	.331	1.397	3.35
1977	.556	.447	.414	1.785	3.68
	Dollars/1,000,000 Btu				
Year					
1972	2.48	1.36	1.64	.45	6.53
1973	2.69	1.61	1.78	.50	6.77
3974	3.72	2.61	3.18	.66	7.79
1975	3.98	2.79	3.20	.99	9.00
1976	4.25	2.95	3.48	1.33	9.82
1977	4.53	3.19	4.36	1.70	10.78

'Natural gas used in agricultural production, such as powering irrigation pumps, is priced at the industrial users' rate.

†Midyear price.

SOURCE: Agricultural Prices Annual Summary 1977; Agricultural Statistics 1977; Gas Facts 1978, American Gas Association.

ENERGY SUBSTITUTION: THE MODEL

As present sources of agricultural energy become more expensive and less plentiful, the development of alternative production processes will become increasingly important. Such processes may permit the substitution of other inputs for farm energy. Estimates of substitutability can be obtained through the use of mathematical models where the results can serve as guidelines at both the farm and national policy levels in evaluating appropriate responses to farm energy shortages. A number of researchers have developed models which assess the substitutability of energy in U.S. manufacturing using both time series and cross-sectional data.' Although such aggregate models provide only a very broad assessment of input-output relationships, they offer valuable insights into energy policy alternatives.

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[3] See D.B. Humphrey and J.R. Moroney, "Substitution Among Capital, Labor and Natural Resource Products in American Manufacturing," Journal of Political Economy, Vol. 83, No. 1, 1975, pp. 57-82; or E.R. Berndt and D.O. Wood, "Technology, Prices and Derived Demand for Energy," *The Review* of Economics and Statistics, August 1975, pp. 259-68.

The model used in this study assumes there is a mathematical expression called a production function which relates the flow of agricultural crop output to the services of four farm inputs: (1) land, (2) hired labor, (3) mechanical energy—which consists of energy used in constructing farm machinery plus the energy used to fuel farm operations, and (4) chemical energy—which represents the energy used in the production of fertilizers and other agricultural chemicals. While other inputs, such as water and operator labor, play a major role in agricultural production, the costs of the four selected inputs represent more than 75 per cent of the total costs associated with the growing of crops in the United States. Moreover, aggregate production functions with these types of broad inputs are more adaptable to the limited amount of available data. For this study, national and state data were primarily developed from the 1974 **Census of Agriculture** and several U.S. Department of Agriculture publications.[4]

As in any econometric study, certain assumptions were made regarding the proper use of the model and the data. Since data were used from only those farms which, according to the **Census of** Agriculture, were primarily engaged in crop production, it was assumed that all of the inputs were specifically used for that purpose. However, it is possible that some of the inputs were actually used in livestock production on those same farms, but these inputs could not be eliminated from the model due to data limitations. On the other hand, there may also have been some inputs used to grow crops on those farms which are primarily engaged in livestock production. If so, these inputs were not counted within the model framework. This type of data aggregation may not reflect the actual substitution possibilities involved with the growing of a single crop by itself. Consequently, while a more specific model (wheat production, for example) may be appropriate, data limitations prevent that type of research.

Despite the simplifying assumptions mentioned, the model and data appear appropriate for the generalized results sought. Moreover, even generalized information on potential substitutability among agricultural inputs can be very useful to farmers and to the firms providing the inputs.

A production function, as indicated earlier, was used to estimate the effect each of the four inputs has on the level of output. In its simple form, a production function expresses how much output can be gained from given quantities of specified inputs. For example, a very simple production function might take the form:

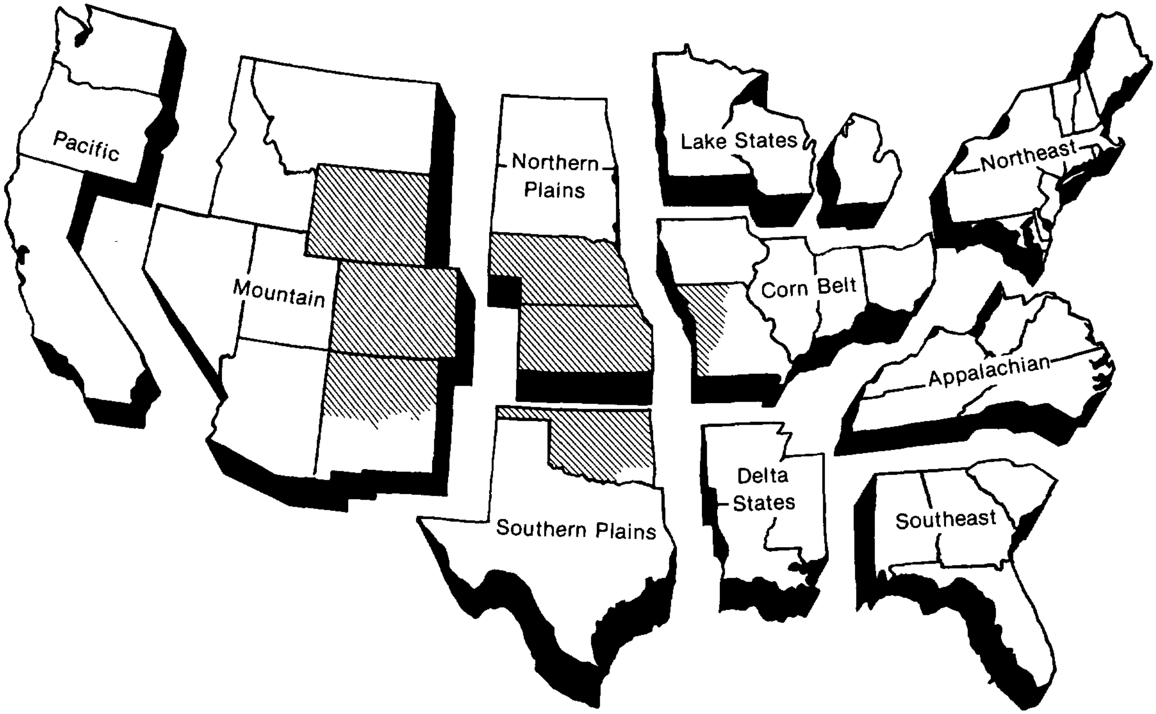
$$Z = aX + bY$$

where Z represents output (i.e., bushels of corn), X and Y denote levels of inputs (i.e., labor hours and tons of fertilizers, respectively) and a and b are parameters that show how much a change in each input affects output. Thus, if "a" were estimated to be 0.5, it would indicate that as the number of labor hours increased by 1, corn production would increase by ½ bushel. And, if "b" were estimated to be 2.4, it would indicate that if 1 additional ton of fertilizer were used, corn production would increase by 2.4 bushels.

The production function used in the model is somewhat more complex than the simple input-output relationship just noted. A very general form for the production function

[4] ***1974 Census of Agriculture.*** U.S. Department of Commerce; ***Energy and U.S. Agriculture: 1974 Data Base,*** U.S. Department of Agriculture; ***Farm Labor,*** U.S. Department of Agriculture, February 28, 1975; ***Agricultural Rices,*** U.S. Department of Agriculture, October 1977; ***Agricultural Prices Annual Summary, 1974.*** U.S. Department of Agriculture.

Figure 1
FARM PRODUCTION REGIONS



Shaded area represents Tenth Federal Reserve District.

SOURCE: U.S. Department of Agriculture.

(known as the **translog** production function) was actually used so as to place no specific restrictions on the estimates of substitutability among the inputs. Table 3 in the Appendix shows the estimated parameters and additional statistical information that was obtained from the actual model used.

The input substitution possibilities were calculated using the parameter values and the means of the input variables. To introduce regional differences of input substitution, there were 12 sets of means used with the parameter values. One set represents the mean levels of the inputs from all 48 continental states. Another set is made up of states which comprise the Tenth Federal Reserve **District.**[5] The remaining 10 sets are based on the **U.S.** Department of Agriculture Farm Production Regions delineated in Figure 1.

MODEL RESULTS

Table 2 shows the elasticities of input substitution. These elasticities are pure **num-**

5 The Tenth Federal Reserve District includes Colorado, Kansas, Nebraska, Wyoming, most of New Mexico and Oklahoma, and 43 counties in western Missouri.

Table 2
ELASTICITIES OF SUBSTITUTION

Region	Land and Hired Labor	Land and Mechanical Energy	Land and Chemical Energy	Hired Labor and Mechanical Energy	Hired Labor and Chemical Energy	Mechanical Energy and Chemical Energy
	Elasticities of Substitution Between					
United States	.77	1.36	.78	1.91	.27	1.19
Tenth District	– .79	1.37	.74	2.01	.29	1.02
Northeast	1.00	1.35	.84	2.12	.23	1.48
Appalachian	.90	1.35	.87	1.99	.25	1.31
Southeast	1.06	1.33	.92	1.97	.26	1.38
Lake States	.47	1.37	.80	1.98	.23	1.16
Corn Belt	– .15	1.39	.80	2.26	.05	1.16
Delta States	.94	1.35	.85	2.00	.25	1.33
Northern Plains	-2.19	1.37	.72	2.05	.60	.96
Southern Plains	.44	1.35	.76	1.79	.31	1.06
Mountain	.70	1.34	.65	1.67	.36	.99
Pacific	1.03	1.35	.72	1.98	.18	1.42

bers which measure the degree or relative ease with which substitution between two inputs may take place, when the prices and quantities of all other inputs remain constant. Thus, the degree of substitutability between one input pair can be compared to the substitutability of another input pair. If the elasticity is positive, the inputs are said to be substitutes for each other. For example, suppose 10 men with shovels were required to dig a large trench. If a machine could dig the trench equally well, it would then be regarded as a substitute input in the production of the trench. A larger positive number reflects a larger degree of substitutability. If the elasticity is negative between a pair of inputs, the inputs are called complements. In this case, the two factors are not likely to replace each other in production. Indeed, a decrease (increase) in the use of one of the inputs would suggest a decrease (increase) in the use of the other. Both inputs, then, would be partly replaced by other factors in order to maintain output. Thus, if the men digging the trench were laid off, their shovels would also be retired. In this case, the labor and the shovels would be complements, and would both be replaced by the machine.

Generally, the results in Table 2 show that each pair of inputs are substitutes, at least to some degree. The table also shows that the substitution possibilities between hired labor and machinery (mechanical energy) hold the greatest potential, whereas the hired labor and fertilizer (chemical energy) tradeoffs would produce relatively less satisfactory results. The only complementary situation involves the land-hired labor relationship, which occurs only in the Tenth District states and in the Corn Belt and Northern Plains region.[6]

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[6] One possible explanation of this is that the marginal productivity of labor is very low or negative in those states which make up the specific regions. Marginal productivity is defined as the change in output resulting from a 1-unit change in the amount of one input while the other inputs are held at fixed levels. Alternatively, the crops grown in one region may not provide the substitution possibilities that crops grown in other regions provide.

The regional results illustrate differences in input substitutability. As shown in Table 2, the elasticity of substitution between land and mechanical energy is quite constant around 1.35 throughout all regions of the United States. However, the results for land-hired labor, hired labor-chemical energy and for mechanical-chemical energy are quite variable from region to region.

The regional differences may be primarily due to differences in the agricultural production patterns that occur across regions. For example, the relatively high elasticity of substitution between hired labor and mechanical energy in the Corn Belt (2.26) may be associated with large-scale corn and soybean production. The lower elasticity in the Mountain States (1.67) may reflect smaller scale and more specialized types of crop production, including widespread use of irrigation. Nonetheless, relatively low elasticities of substitution for most input pairs in the Mountain region suggests a production pattern and input mix that is relatively inflexible. Similarly, the elasticities of substitution between mechanical and chemical energy suggest such a substitution in the Northeast may be substantially easier than in the Northern Plains. Moreover, the ease of replacing hired labor with chemical energy (or vice versa) is also rather limited throughout all regions. Thus, if agriculture were to make large-scale changes in its production input mix, regional differences should probably be considered.

The elasticities of substitution between input pairs in the Tenth District states are generally very similar to those for the United States. One major exception is found in the case of land and hired labor. For the United States, these inputs are substitutes, while for the Tenth District they are complements and, as a consequence, would not be expected to substitute for each other.

It should be noted that these substitution elasticities may change if the relative prices of inputs change or if the productivity of a particular input increased. However, given the production and price relationships in 1974, these estimates appear quite reasonable when compared with other research findings.[7]

POLICY OBSERVATIONS

The model's results are of a general nature and can best be used to point out policy opportunities in the event economic or political circumstances force farmers to consider market changes in the mix of resources used in agricultural production. Within the framework of the model, a number of policy observations are possible.

Input Substitution

The model's results **confirm** the general assertion that acreage allotment and set-aside programs are not particularly effective means for limiting crop output.[8] Mechanical energy and chemical energy are readily substituted for land in the production process. Consequently, even moderate cutbacks in acreage are easily offset by utilizing more machinery and chemicals (including fertilizer) to increase production per acre and thus maintain total production. Conversely, if the energy inputs in machinery and chemicals were cut back for some reason, flexibility exists to maintain substantial production by farming more acres less intensively. Finally, the larger elasticity number for the mechanical energy-land substitution indicates that substitution is markedly

[7] See Hans Binswanger, "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution," ***American Journal of Agricultural Economics.*** **May 1974, pp. 377-86.**

[8] D. E. Hathaway, ***Government and Agriculture: Public Policy in a Democratic Society*** **(New York: Macmillan Co., 1963), pp. 296-301.**

easier between that pair of inputs than between chemical energy and land.

The model's results also indicate that mechanical energy (machinery) is the most flexible input of the four included in the model. Mechanical energy readily substitutes for hired labor quite uniformly across all production regions, although the substitutability is highest in the major food and feed grain producing regions. Somewhat more diversity is found across regions when mechanical energy-chemical energy substitution is examined. Nonetheless, mechanical energy would be quite a satisfactory substitute for many kinds of chemical energy, should spot shortages of chemicals occur within a growing season or over a limited number of growing seasons. For example, cultivation could at least partly substitute for chemical weed control. Conversely, if agriculture were faced with fuel shortages, total crop output could be maintained by diverting some petroleum stocks to the production of chemicals and fertilizers.

The degree of substitutability between mechanical energy and chemical energy is quite important. Some researchers have suggested that agriculture should return to less energy-intensive production practices to conserve energy.[9] Thus, by using more land and labor, more energy could be saved. The results of this research indicate, however, that the substitution of nonenergy inputs for energy inputs is limited by both regional production differences and by the type of energy for which the substitution is made. For example, if conserving mechanical energy is important, both land and hired labor (both nonenergy inputs) would be better substitutes than chemical energy.[10]

[9] Michael J. Perelman, "Mechanization and the Division of Labor in Agriculture," *American Journal of Agricultural Economics,* Vol. 55, No. 3, August 1973, pp. 523-26.

[10] The results, however, indicate that chemical energy may be a better substitute for mechanical energy than land in the Northeast, Southwest, and Pacific regions.

On the other hand, if chemical energy conservation is given priority, the use of mechanical energy is always a more realistic substitute than are the two nonenergy inputs (land and hired labor). Thus, the substitution of one form of energy for another may be more practical than using nonenergy-consuming substitutes. These results suggest caution for those who urge widespread shifts from energy-based inputs to human-labor inputs in agricultural production. This finding also adds support to the intuitive assertion by agricultural producers that it is impractical to make significant substitutions of labor for many energy inputs.

On balance, it appears that agricultural producers do have a surprising amount of flexibility to substitute inputs while maintaining output levels in the event that restrictions on energy availability occur. In the case of some inputs, effective substitution can occur within a production season, as in mechanical-chemical energy substitution. Other kinds of substitution are of a longer term nature and could occur over several years, as in shifting to less intensive production practices.

CONCLUSION

The use of energy in agriculture has allowed for large increases in output and productivity, and has provided the nation with a steady supply of food at reasonable prices. However, present U.S. agricultural production is heavily dependent upon energy availability. Due to the possibility of energy shortages or rising energy prices, farmers may be forced to use other inputs as substitutes for energy.

The empirical evidence presented here suggests that farmers using conventional inputs do have some substitution alternatives to maintain production. The evidence also suggests that a national energy policy for agriculture should be somewhat modified to incorporate regional production differences. Moreover, even without large-scale shifts in production methods, there are ways in which farmers can conserve energy. Better management and more efficient operations will become increasingly important as energy prices escalate. Finally, caution is suggested for those who urge widespread shifts from energy-based inputs to human-labor input in agricultural production.

APPENDIX

For this study, a translog production function was used to estimate the required parameters. It takes the form

$$\ln Q = \ln a_0 + \sum_i a_i \ln X_i + \tfrac{1}{2}\sum_i \sum_j b_{ij} \ln X_i \ln X_j$$

where ln represents the natural logarithm, Q denotes output, a_0 is the intercept coefficient, a_i and b_{ij} are the coefficients to be estimated and X_i and X_j are the levels of the various inputs. The specification and restrictions of this model allow the parameters to be estimated using full information maximum likelihood estimation applied to a system of three marginal productivity equations. For a review of the procedure, see the article by Humphrey and Moroney as listed in footnote 3.

Table 3 shows the estimated parameter values (the a_i's and b_{ij}'s from the translog equation) obtained from the model. By themselves, the parameter values have little economic meaning but, when used in the appropriate calculations, the substitution possibilities among the four inputs can be examined.

Table 3
ESTIMATED PARAMETER VALUES AND T-STATISTICS*

	j Component				
	Intercept	Land†	Hired Labor	Mechanical Energy	Chemical Energy
Land	.227873†	.059126			
Hired Labor	–.361154	–.023888	.084573		
	(-5.25715)		(12.9384)		
Mechanical Energy	.483268	.007482	–.04002	.077721	
	(4.70931)		(-6.9187)	(6.01868)	
Chemical Energy	.650013	–.04272	–.020665	–.045183	.108568
	(4.88893)		(-2.66588)	(-4.29044)	(6.30154)

*Critical values with 135 degrees of freedom are $t_{.05}$ = 1.96 and $t_{.01}$ = 2.57.

†Implied estimates computed using the mathematical constraints placed on the model.

NOTE: The parameters were estimated using three marginal productivity equations representing hired labor, mechanical energy, and chemical energy. The adjusted coefficient of determination (R^2) and F-test values for each equation are, respectively: hired labor, .771 and 39.44; mechanical energy, .710 and 28.85; chemical energy, .357 and 7.11. Each of the F values is significant at a 1 per cent level.

The t-statistics (shown in parentheses) indicate that all of the estimated parameters are statistically significant. An estimated parameter with a t-statistic greater than 2.57 in this case indicates that there is only a 1 per cent chance that the actual parameter value is zero. It should be noted that the actual parameter value may not be the same as the estimated value. This is true because the estimated value is obtained using a sample of an entire population of observations. Thus, the larger the t-statistic (regardless of its sign), the better the estimated value is in approximating the actual value.