

ABSTRACT

Determinants of the Postwar Farm Machinery Stock

Emanuel Melichar
Board of Governors of the Federal Reserve System

The stock of farm machinery, now valued at \$34 billion and requiring nearly \$5 billion annually in replacement expenditures alone, is a key variable in any examination of the capital and credit requirements of agriculture. Long-run projections of the stock are sought, for example, by agencies that could effect changes in institutional arrangements that influence the availability of bank loans for machinery purchases.

Several projections of stocks in 1980 have been published. However, their diversity makes one suspect their usefulness. Furthermore, the passage of time has provided more data on the structural characteristics of the postwar period. Therefore, the determinants of postwar stocks are re-explored using an approach similar to that of the previous study by Heady and Mayer.

The most striking new finding is the apparent emergence of a logical and strong relationship between real machinery stock and relative machinery cost as measured by the ratio of machinery prices to farm wage rates. Such a relationship had been sought by numerous previous investigators without success. Other significant variables in the equation presented are acres of harvested cropland and the number of farms.

A projection of real machinery stock in 1980, employing the model and projected values of explanatory variables identical to those used by Heady and Mayer, shows the stock at \$41.8 billion, or substantially below the Heady-Mayer projection. However, this result is also much higher than an earlier projection by Heady and Tweeten.

If machinery prices continue to rise at the recent average of 2.5 per cent annually, current-dollar stock in 1980 would total \$53.5 billion. This figure is substantially above previous current-dollar projections made by Brake and Doll.

Determinants of the Postwar Farm Machinery Stock

Emanuel Melichar
Board of Governors of the Federal Reserve System

The stock of farm machinery, equipment, and motor vehicles is a key variable in any examination of the capital and credit requirements of agriculture. With the stock now valued at \$34 billion, annual expenditures approaching \$5 billion are required simply to maintain the current level. Expansion of the real stock requires investment beyond such replacement spending, and in turn leads to still greater replacement costs. Thus, in many recent years machinery expenditures have probably exceeded even the annual capital flow required to effect transfers of farm real estate, and have represented over 40 per cent of total farm capital flows [10, pp. 25-26].

Long-term projections of probable changes in this important component of farm capital are of interest to several groups. For example, machinery manufacturers need a basis for planning their own plant expansion. Such projections are also sought by agencies that can exert a long-run influence on the volume and terms of loans available to farmers. For instance, availability of bank loans for machinery purchases might be increased by improving the access of rural banks to national capital markets or to the discount facilities of the Federal Reserve Banks and Federal Intermediate Credit Banks. Such efforts to alter institutional arrangements are more likely to be pursued if probable future needs can be demonstrated in a seemingly reliable manner.

Unfortunately, the record of recent long-term projections of the farm machinery stock is not one to inspire much prima facie confidence in the results of such endeavors. The several published projections for 1980 noted herein, for instance, are so diverse that most must necessarily be proved far off the mark.

Furthermore, with ten years to go, all but one already appear to be too low, but the sole exception seems much too high!

The difficulties in analysis and projection are a result, in large part, of the erratic past record presented by the real machinery stock. Since World War II there have been two periods of expansion and one of decline. A large and rapid postwar expansion ended in 1955. Seven years of downward drift were succeeded by renewed growth that has been at least temporarily halted in 1969. Investigators who would project on the basis of this postwar record, illustrated in Figure 1, clearly have a problem, whether they desire simply to extrapolate the trend, or to go through the process of specifying and estimating a more complex structural or statistical relationship. In either case, their results are greatly influenced by how much of the early postwar expansion they allow to effectively enter the estimation process. In addition, recent past studies have also been affected by how many years, if any, of the record of the more recent expansionary period were available to the investigator.

In the early 1960's Heady and Tweeten, after an extensive investigation of all types of farm investment demand, concluded that a reasonable projection of the real machinery stock for 1960-80 might be secured by a linear extrapolation of the 1952-60 trend [8, pp. 490-492]. The resulting stock of \$32.1 billion in 1980 (in 1970 dollars) is shown by projection HT in Figure 1. It appears that the Heady-Tweeten expectation of a future "'mature' agricultural economy in terms of machinery" has been discredited by the events of the past decade.

In the mid-1960's, Heady and Mayer projected the real machinery stock in 1980 as part of an assignment for the National Advisory Commission on Food and Fiber [6, p. 21-22, 75; 7].^{1/} They estimated a machinery demand equation for each of ten regions, using data for 1949-64. Thus, in contrast to the earlier Heady-Tweeten decision, their statistical base included a greater part of the strong upward surge of the immediate postwar years, and so their equations

^{1/} The author gratefully acknowledges the receipt of additional information concerning these estimates, kindly supplied by Dr. Mayer.

for most regions were dominated by a strong trend variable. Their national projection for the 1980 machinery stock (in 1970 dollars) in the "feed-grain model" is \$50.8 billion, illustrated by projection HM in Figure 1. Rather formidable capital and credit flows would be required in the fulfillment of this projection [9].

The explanatory variables employed by Heady and Mayer, and the percentage of the projected 1965-80 national increase for which each was responsible, were as follows: the ratio of machinery prices to farm wage rates (+14%), the quantity of farm labor (-3%), acres of cropland harvested (+7%), number of farms (+2%), and time (+79%). In view of the exceptional strength of the trend variable, one wonders whether Heady and Mayer may have picked up some of the postwar "catch-up" demand by going back to 1949 for their statistical base. Also, five additional years of postwar data are now available to help indicate an appropriate structure for the demand equation. Therefore, relationships between the real machinery stock and five explanatory variables (defined in Table 1) similar to those employed by Heady and Mayer were re-explored at the national level.

The most striking new finding--one with very significant implications for the equations and projections--is the apparent emergence of a significant relationship, with the "expected" sign, between machinery use and relative machinery cost as measured by the ratio of machinery prices to farm wage rates. As shown in Figure 2, from 1946 to 1950 the real machinery stock was increased greatly even though machinery was becoming much more expensive relative to labor. The more logical opposite relationship appeared in 1950-52. But for the next 12 years there was little change in either the relative cost ratio or in the machinery stock, which was hardly conducive to estimation of a structural relationship. After study of the points plotted for 1949-64 in Figure 2, it is not surprising that relative machinery cost was significant in only five of Heady-Mayer's ten regional equations, and exhibited only limited explanatory power. This result agreed with previous studies of machinery demand. Neither Cromarty

[2, p. 40] nor Heady and Tweeten [8, p. 292] found a significant relationship over a combined period of prewar and postwar years. The variable had also disappointed these and several other investigators of demand for farm tractors in the United States [4, p. 35; 5, p. 194; 11, p. 902].

But as Figure 2 also demonstrates, data for 1964-69 exhibit a consistent correlation between relative machinery cost and the real machinery stock, and with these years added the entire period 1950-69 yields a strong statistical relationship that dominates machinery demand equations estimated over this time. Also, the problem of how many of the early postwar years to exclude from the statistical base in estimating currently appropriate structural equations can be logically resolved by reference to the pronounced structural shift that occurred around 1950. Thus 1950-69 is used as the base for the estimates that follow.

The other four explanatory variables were tested in alternative combinations that had logical appeal. Among them, harvested cropland tended to have significant coefficients with the expected sign. The decline in harvested cropland over 1952-62, from 349 to 295 million acres, probably helps explain the 1955-62 decline in the machinery stock.

Two of the remaining variables, quantity of farm labor and number of farms, each had strong linear trends and thus were highly correlated with each other and with the fifth variable, time. Of the three, the number of farms showed the best explanatory power when used along with relative machinery cost and harvested cropland. As an admitted rationalization, if the main purpose of a trend-type variable in this equation is to serve as a proxy for the advance of technology, perhaps the rate of decline in farm numbers serves as a better proxy for the rate at which technology is being applied than does either an unwavering time trend or the labor measure that includes a hired labor component that is also influenced by the machinery-labor cost ratio already represented in the equation.

The addition of any of these trend-type variables to the equation reduced the apparent influence of relative machinery cost by about one-third. The trend variable (number of farms in the estimates that follow) may be capturing part of the influence rightly due to relative machinery cost, or vice versa. The large degree of uncertainty on this score must be considered when viewing the results presented in Tables 2 and 3.

The estimated demand equation for the real machinery stock is shown in Table 2. The stock was valued in January 1, 1970, dollars (the values of the current and real machinery stocks were set equal as of January 1, 1970). The coefficients for cropland and farms are easily interpreted. With all other factors held constant, the machinery stock tends to increase by \$90 for each acre added to harvested cropland and to decrease by \$3,065 for each farm that disappears. The effect of changes in machinery prices and farm wages is more complex. For every point by which the percentage rise in farm wages exceeds the percentage rise in machinery prices, the index of relative machinery cost falls by about one point and so the real machinery stock tends to increase by about \$226 million. For instance, if wages should rise by 6 per cent and machinery prices by only 3 per cent from 1969 levels, the relative machinery cost index (1969 = 100) would fall to 97.17, or by 2.83 points, and so the real machinery stock would tend to increase by \$639 million ($2.83 \times \226 million).

To use this equation to project 1980 machinery stock, 1980 values must first be projected for the explanatory variables. Values similar to those used by Heady and Mayer are shown in Table 3. Using these values, the increase in the real machinery stock from 1969 to 1980 (in 1970 dollars) is projected at \$7.2 billion, which would bring total 1980 stock to \$41.8 billion. This turns out to be midway between the Heady-Tweeten and Heady-Mayer projections, as shown in Figure 3.

Projections in real terms may satisfy some uses; for instance, plant expansion planning by machinery manufacturers. However, farm capital and credit demands stimulated by a desired expansion in real machinery stock are made and met in current dollars. Thus the price element of stock value is just as important as the real element. Prices of farm machinery and motor vehicles are determined largely by trends and events in the nonfarm business sector and should be the subject of a separate study. It is interesting and perhaps useful, however, to note the current-dollar stock values that are implied by our projections if farm machinery prices continue to advance at the pace of the past two decades, during which the average annual increase was 2.5 per cent.

If this average rate of machinery price inflation continued through the next decade, prices in 1980 would be 28 per cent higher than in 1970, and the projected machinery stock of \$41.8 billion in 1970 dollars would have a current value of \$53.5 billion. With the same revaluation, the Heady-Mayer projection for 1980 becomes \$65.0 billion, and the Heady-Tweeten projection, \$41.1 billion.

Two other investigators have projected 1980 machinery stocks in current dollars. In 1966, Brake projected a total of \$36 billion [1, p. 1541]. In 1968, Doll projected a machinery stock of \$60 billion for the year 2000, which works out to an annual growth rate of 2.1 per cent for real and price components combined, and ~~for~~ an implied 1980 value of \$40 billion [3, p. 15]. If machinery prices do continue to rise, both of these projections appear rather low in the light of our new analysis of the determinants of the real component.

References

- [1] Brake, John R., "Impact of Structural Changes on Capital and Credit Needs," Journal of Farm Economics, 48:1536-1545, December 1966.
- [2] Comarty, William A., The Demand for Farm Machinery and Tractors, Michigan Agricultural Experiment Station Technical Bulletin 275, November 1959, 72 pp.
- [3] Doll, Raymond J., "Machinery and Other Equipment--Agriculture's Largest Input," Monthly Review, Federal Reserve Bank of Kansas City, November 1968, pp. 11-16.
- [4] Fox, Austin, Demand for Farm Tractors in the United States--A Regression Analysis, Agricultural Economic Report No. 103, Economic Research Service, U. S. Department of Agriculture, November 1966, 50 pp.
- [5] Griliches, Zvi, "The Demand for a Durable Input: Farm Tractors in the United States, 1921-57," in The Demand for Durable Goods, edited by Arnold C. Harberger, Chicago, The University of Chicago Press, 1960, pp. 181-207.
- [6] Heady, Earl O., and Leo V. Mayer, Food Needs and U. S. Agriculture in 1980, Technical Papers--Volume I, National Advisory Commission on Food and Fiber, Washington, D. C., August 1967, 116 pp.
- [7] Heady, Earl O., and Leo V. Mayer, "Aggregate Demand for Farm Machinery," Paper presented to the Conference on Computers and Farm Machinery Management, Chicago, December 9-10, 1968, 15 pp. (mimeo.).
- [8] Heady, Earl O., and Luther G. Tweeten, Resource Demand and Structure of the Agricultural Industry, Ames, Iowa, Iowa State University Press, 1963, 515 pp.
- [9] Melichar, Emanuel, "Farm Capital and Credit Projections to 1980," American Journal of Agricultural Economics, 51:1172-1177, December 1969.
- [10] Melichar, Emanuel, and Raymond J. Doll, Capital and Credit Requirements of Agriculture, and Proposals to Increase Availability of Bank Credit, Project 24, Fundamental Reappraisal of the Discount Mechanism, Board of Governors of the Federal Reserve System, November 6, 1969, 160 pp.
- [11] Rayner, A. J., and Keith Cowling, "Demand for Farm Tractors in the United States and the United Kingdom," American Journal of Agricultural Economics, 50:896-912, November 1968.

Table 1. Variables employed in the regression analysis

Real machinery stock--The stock of motor vehicles and machinery on farms measured in millions of January 1, 1970 dollars (the values of the current and real machinery stocks were set equal as of January 1, 1970). Average of values for beginning and end of each year. Source: The Balance Sheet of the Farming Sector, U. S. Department of Agriculture, January 1970, p. 32. The Agricultural Finance Branch of the USDA kindly supplied data in millions of dollars.

Relative machinery cost--An index (1969 = 100) of the ratio of the index of prices paid by farmers for farm machinery to the index of prices paid by farmers for hired farm labor. Source: Agricultural Prices, 1969 Annual Summary, U. S. Department of Agriculture, June 1970, pp. 8 and 11.

Harvested cropland--Area in 59 principal crops harvested as reported by SRS plus acreages in fruits, tree nuts, and farm gardens, in millions of acres. Source: Economic Tables, ERS, January 1970, p. 5.

Farm labor--Index (1957-59 = 100) of total farm labor input. Source: Economic Tables, ERS, January 1970, p.3.

Number of farms--Number of farms, in thousands. Source: Farm Income Situation, U. S. Department of Agriculture, July 1970, p. 46.

Time--Linear trend, measured by the last two digits of the year.

Table 2. Regression Equation for the Real Machinery Stock
(millions of 1970 dollars)

Explanatory variable	Coefficient	t
Constant	39,834.379	4.15
Relative machinery cost (index, 1969 = 100) . . .	-225.904	4.38
Harvested cropland (millions of acres)	+ 90.083	3.18
Number of farms (thousands)	- 3.065	3.36

$\bar{R}^2 = .904$, $F(3.16) = 60.73$, S.E.E. = 814, D-W ratio = 1.03

Table 3. Projection of the Real Machinery Stock in 1980
(millions of 1970 dollars)

Explanatory variable	Value of variable			Coefficient	Projected effect on machine stock, 1969-80 (millions of 1970 dollars)
	1969	Projected			
		1980	Change 1969-80		
	(A)	(B)	(C)	(D)	(C x D)
Relative cost	100.0	85.9	-14.1	-225.904	+3,185
Cropland	294	306	+12	+ 90.083	+1,081
Number of farms	2,971	2,027	-944	- 3.065	<u>+2,893</u>
					7,159

Figure 1. Real machinery stock, 1945-69,
and two projections to 1980 *
(Billions of 1970 dollars)

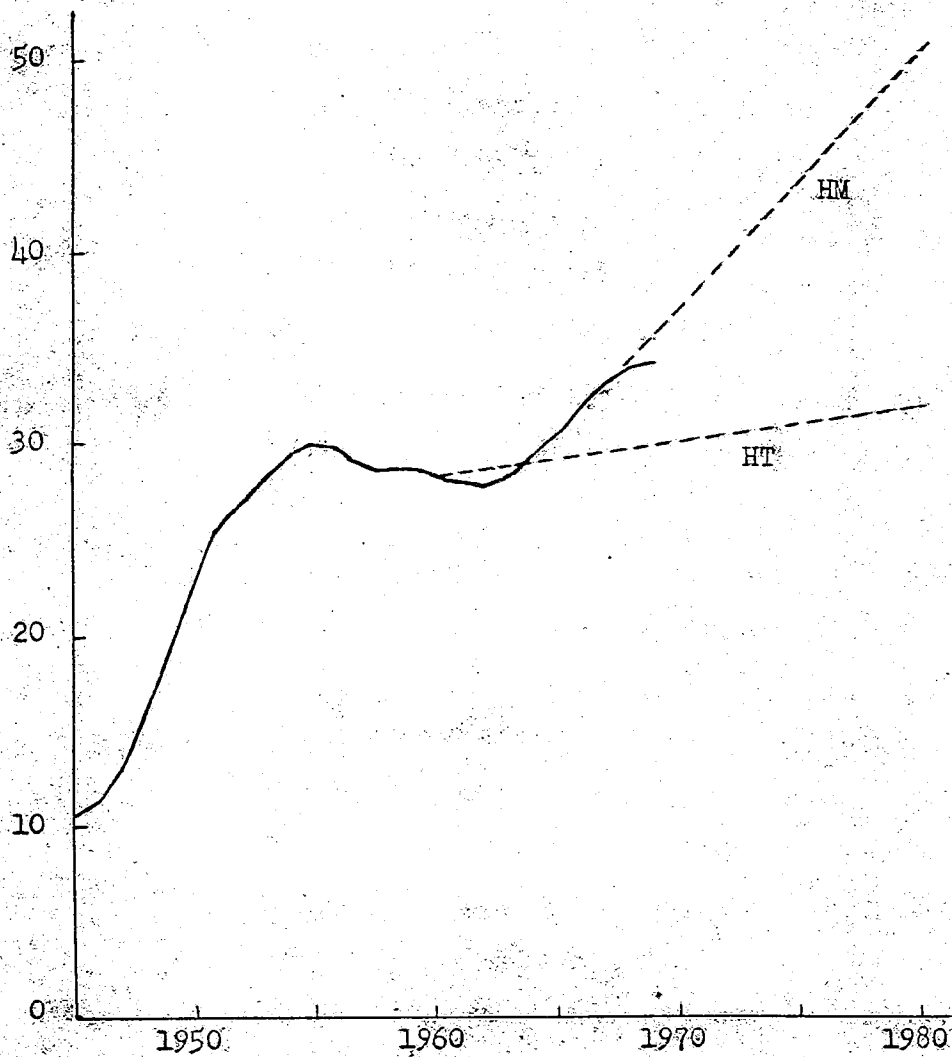


Figure 2. Relationship between real machinery stock and relative machinery cost, 1945-69

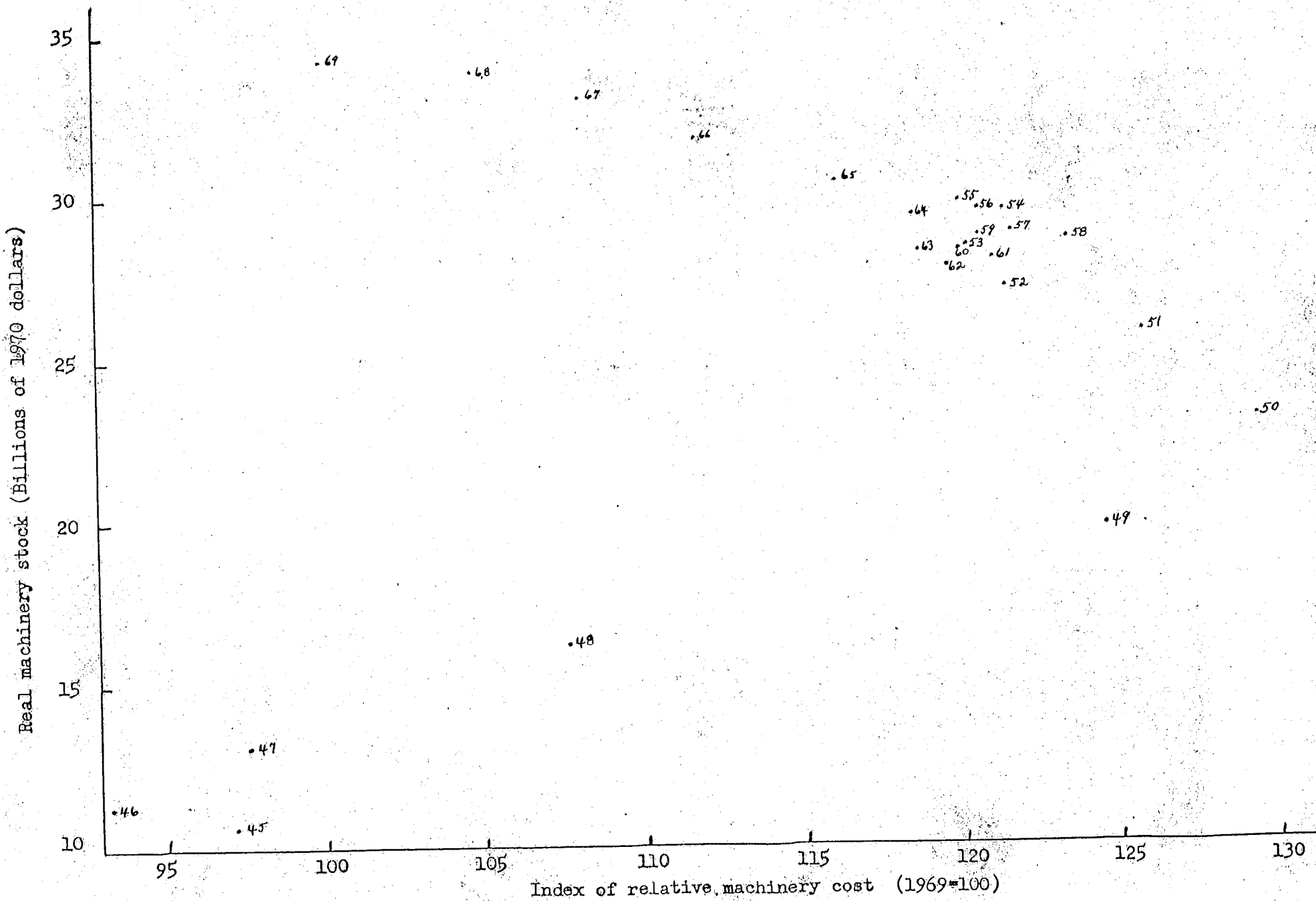


Figure 3. Real machinery stock, actual and predicted, 1950-69, and projection to 1980
(Billions of 1970 dollars)

