CAPACITY MEASUREMENT IN THE U.S. AGRICULTURAL AND NONAGRICULTURAL SECTORS: A LITERATURE REVIEW

By Heinz Spielmann[1]

In an examination of the literature of agricultural economics from the fifties on, the author presents several definitions of production capacity of U.S. agriculture. No satisfactory measure of such capacity exists nor is there a viable, generally acceptable definition of the term. Literature of the nonagricultural sector contains some appropriate definitions and methodologies associated with capacity measurement. After discussing and evaluating several of these, the author suggests that some of them may provide help in making agricultural methods more useful.
Keywords: Agricultural production capacity, production capacity, capacity measures.

INTRODUCTION

A major problem confronting U.S. agriculture through most of the fifties and midsixties was the continued buildup of surpluses which proved costly to the Government and depressed market prices. Various policy attempts were made to mitigate this situation. Attempts on the demand side included the school lunch, food stamp, and P.L. 480 programs. On the supply side, producers were encouraged to abstain from continuing their high levels of production.

The agricultural economics literature of that time reflected a concern about excess capacity. Many long-range projections predicted continued surpluses on the supposition that the momentum of technological advance would keep food production well ahead of domestic population growth and of increasing per capita demand. The belief that the deficiency gap in the world's food budget would be closed by the eighties was reinforced by achievements of the Green Revolution. Pockets of starvation and near starvation were ascribed to faulty distribution, and the domestic quest for reduced production continued. Questions of precise measurement of agricultural capacity were not considered.

Following the surge in U.S. grain exports in 1972-73, it became clear that publicly imposed limits on production had worked only too well and that grain inventories had fallen dangerously low. Shortages occurred in fertilizer, energy, labor, and implements (particularly machinery). These shortages raised questions about the capacity of U.S. agriculture to produce food and fiber. In recognition of the international political impact of U.S. food production, and in view of domestic policies to make commodities increasingly reliant on the market rather than the U.S. Treasury, measuring agricultural capacity is assuming heightened importance.

A search of the literature for a suitable measure of agricultural capacity leads to the realization that no such measure seems to exist, nor is there a viable and generally acceptable definition of the term.

The literature of the nonagricultural sector, however, contains some appropriate definitions and methodologies associated with capacity measurement. Interest in this subject emerged about 1948. A number of more or less effective measurements have been developed, some of which are in use.

This article describes some of the efforts in both sectors to define and measure capacity and utilization. Methods for constructing capacity indexes are reviewed and their theoretical bases discussed.

Why measure capacity? It is important to determine the extent to which agricultural output can meet the serious food shortages throughout the world. Policy decisions depend on macroeconomic projections of capacity of agriculture, the conditions and policies required to use capacity optimally, and the efforts required to increase capacity. Microeconomic studies show that industry capacity utilization and operating costs are correlated, and that industry utilization rates are reliable indexes of capital expansion, early indicators of changes in profits, and pointers to hidden bottlenecks in the system.

DEFINITIONS OF PRODUCTION CAPACITY

The Agricultural Sector

The capacity of U.S. agriculture to produce is described in the literature in different ways. Brandow states that excess capacity exists when supply exceeds demand (*3*).[2] Converse conditions indicate undercapacity. Optimal capacity utilization is seen as equivalent to a market equilibrium wherein quantity supplied equals quantity demanded.

Quance and Tweeten define excess capacity as "... farm production in excess of market utilization at socially accepted prices" (*29*, p. 57). A measure of excess production is established by summing agricultural prod-

[1] Heinz Spielmann is a professor of agricultural economics in the Department of Agricultural Resource Economics at the University of Hawaii. While researching material for this article, he was on sabbatical leave in the National Economic Analysis Division of ERS.

[2] Italicized numbers in parentheses refer to items in References at the end of this article.

ucts held by the Commodity Credit Corporation (CCC) plus P.L. 480 shipments to foreign countries plus the potential from land withdrawn from production. Total capacity equals excess production plus commercial production. Excess capacity is the ratio of excess production to total capacity. The required conditions underlying attainment of capacity are not clearly established.

In a similar definition, Tyner and Tweeten view excess capacity as production (including potential production which could be derived from Government-directed land diversions) which exceeds commercial utilization. Excess capacity is calculated by dividing total production into the derived "excess" (*32*).

Culver and Chai made straight-line projections to the nineties of per capita demand for agricultural products, population, and gross national product (*6*). They also projected production, yield, and prices. Capacity is interpreted as the projected capability of agriculture to meet demand.

In an ERS article, capacity is the agricultural production projected for 1980 to 1985 under favorable prices and the assumption that all required inputs will be available (*34*).

Heady and Mayer define excess capacity as "cropland not needed to fill the demand" for agricultural products under various Government policy conditions (*17*). They predict that under conditions of no Government interference and free markets in 1980, considerable excess capacity in terms of available but unused acreage will exist, given the availability of all other inputs (*18*). In this definition, capacity is related to capital holdings.

In some of the literature, a definition of capacity can only be inferred, even when the title contains the words "excess capacity." One can infer from Ruttan and Sanders that excess capacity exists if agricultural production exceeds market demand (*30*). This definition resembles the concepts developed by Tweeten, Quance, and Tyner.

In a second study by Tyner and Tweeten, optimal resource use concepts are developed and excess capacity is defined as inefficient resource allocation (*33*). Many resources, particularly labor and land, have been overcommitted to agricultural production, which has resulted in low returns. Capacity means that level of production where optimal efficiency in resource use (least cost) is achieved at the same time that demand requirements are met. If one abstracts from the demand part of this definition, one comes very close to the concept of nonagricultural capacity described in the next section.

Several points stand out thus far:

1. Definitions of capacity vary considerably. Capacity usually is made dependent on both supply and demand. An excess capacity exists if more is produced than demanded in commercial markets. It may be inferred that capacity represents an equilibrium commercial market position wherein quantity demanded equals quantity supplied. Public storage, exports under P.L. 480, and potential production from land withheld all represent excess capacity. A few authors relate capacity to variable and fixed capital, and they align commercial demand with supply.

2. The assumptions underlying definitions of capacity also vary considerably. They range from normal conditions, wherein prices are socially acceptable, and continued technological improvements are expected, to substantial changes in public policy. An assumption of available fixed and variable inputs is explicit or implicit; limited inputs are not considered as limits to productive capacity.

3. Many authors did not define the concept of capacity explicitly, calling upon the reader to infer a definition from a series of "clues" in the text.

The Nonagricultural Sector

Capacity in the nonagricultural literature is frequently defined as the maximum output that can be produced with existing plant and equipment over a specified period of time. A profound definitional problem arises from the term "can be produced." There are two basic approaches: the so-called *engineering* approach and the *economic* approach. In most cases, both assume a normal operating intensity for the industry. For example, where operations use 3 shifts 24 hours a day, "normal" operations are around the clock. For other industries, an 8-hour day of operation is "normal."

The "engineering" approach specifies the maximum production from a plant using normal operations, without regard to cost or profit (*19*). Klein views the engineering approach as that output associated with fully utilized labor, capital, and other relevant factors of production (*21*).

In the "economic" approach, carefully established and precise underlying conditions are considered, including costs and optimizing objectives. It is here that divergences in capacity definition are most prominent.

The majority of investigators define capacity relative to shortrun, least-cost operations of the firm. Capacity in economic terms refers to a point where the U-shaped, shortrun, average cost curve is lowest. The difficulties with this approach are well known and numerous. First, it is uncertain whether cost curves can be established and whether the minimum of a cost/output ratio can be determined. Second, the U-shape of average cost curves may be only coincidental. Average cost curves of some firms appear to be flat-bottomed, others seem to show gradual decline, while others appear to reach a minimum very rapidly but only gradually rise thereafter (*7*; *26*).

With divergent cost conditions in mind, DeLeeuw suggests that capacity should be measured along the marginal cost function at a "level of output at which shortrun marginal costs are (x) percent above minimum shortrun average costs" (*9*). This criterion would imply that the cost of an additional unit of output would incur sharply higher unit costs than would the cost of the most efficient output. The value of *x* would be uniform throughout each industry and it would be estimated empirically.

Another interpretation of capacity is related to the capital stock held by an individual firm. Given a constant stock of capital, an output may be reached wherein the acquisition of additional capital stock may be advisable (*26*, p. 95). At this point, which will likely occur before the minimum average cost is reached, lower operational costs can be achieved by appropriate changes in plant and equipment. This concept defines capacity as an economic limit to the rate of output of existing fixed capital.

This review discloses a variety of definitions of nonagricultural capacity. It will be shown later that these lead to divergent methods of numerical estimation. Most of these methods start from the firm level and aggregate to weighted industry indexes. Relatively close agreement exists on numerical estimates of capacity. Conceptually, there are several points of apparent concurrence:

1. Continued availability of fixed and variable inputs.
2. No changes in technology or in the *modus operandi* of individual firms or in their product mix.
3. The quantity of capital stock, plant, and equipment is held constant for the relevant output.
4. Capacity as a cost concept is defined to occur at minimum average cost for the firm.
5. Capacity is independent of demand.
6. The concept of capacity is viewed at the firm level.

No clear cut definition of capacity was found in either the agricultural or nonagricultural literature. However, the statement that "capacity is that output which can be produced at minimum average total cost, given existing stock of plant and equipment and existing techniques and factor prices" appears to capture the general consensus in the nonagricultural literature.

CAPACITY MEASUREMENT METHODOLOGY AND EVALUATIONS

The Agricultural Sector

The empirical methods employed to derive measures of agricultural capacity are not discussed by some of the authors reviewed. Others base capacity measures on simple straight-line projections of production, land use, and labor data. Others provide complete descriptions of the methodology employed.

Heady (*16*) estimates U.S. production of 7 major crops in 144 producing and 31 consuming regions. A linear program establishes optimal production levels and transportation flows for each crop in each region. Projections of yield and expected consumption are made for 1980. The outcome is a regional pattern of least-cost production with flows for consumption in those regions which have lower relative advantage. This system incorporates estimated and well-defined demand parameters, and considers Government policy conditions ranging from free markets to acreage restrictions.

Tyner and Tweeten use a simulation model to test the ability of the agricultural sector to divest itself of its "excess" capacity and to return to "normal" capacity operation (*33*). The model uses recursive aggregate supply and demand equations. One can infer optimal policies to induce operation at "capacity." While the authors speak of agriculture's ability to remain viable, they use their model to simulate attainment of capacity output through Government programs.

Some writers, although they do not define capacity, couch their capacity predictions in a variety of scenarios. Brandow speaks of standard and high demand situations, thus making capacity a function of demand (*3*).

Future conditions assumed in an ERS article center around four points (*34*):

1. Farm product prices favorable for increased production,
2. No restrictions in land use,
3. Adequate input supplies, and
4. Normal growing conditions.

Quance and Tweeten show presence or absence of excess capacity under various Government policy conditions, differing demand and supply elasticities, and varying supply and demand shifts (*29*).

Heady and Mayer assume that demand will continue to increase proportionally with population and income (*17*). They assume the rate of increase in productivity will be that which prevailed in 1950-65 and export demand will continue at 1965's levels. These assumptions imply continued excess agricultural capacity and, therefore, reduced cropland acreage requirements.

Many of the writers take an "engineering" approach to agricultural capacity assessment by adding all possible available land and inputs and comparing these with demand estimates. Authors who use a more "economic" approach tend to more pessimistic outcomes.

Highly diverse methods of agricultural capacity determination are employed by various investigators. However, the empirical methods are not always consistent with the concepts of "capacity" as previously defined. In addition, there is a considerable lack of data on which to base capacity estimates. As a consequence, estimates of agriculture's current and future capabilities differ widely.

The Nonagricultural Sector

A number of private and Government economists have, in addition to attempting a clear, uniform definition of capacity, addressed themselves to various methods of capacity measurement. Four such capacity measures will be reviewed and evaluated:

- McGraw-Hill measures of capacity and industrial rates.
- Manufacturing Capacity Index of the Bureau of Economic Analysis, U.S. Department of Commerce.
- Wharton School Index of Capacity Utilization.

- Federal Reserve Board Capacity Utilization Index for Manufacturing and Major Materials.

I shall also touch on a system used by the Industrial Conference Board and briefly discuss two additional theoretical approaches.

Some of these indexes and systems date back to 1948; others are of quite recent origin. Methodologies vary considerably. The outcomes of measurements, however, are much closer to each other than was found in the agricultural sector. Among the reasons may be these: the various agencies involved in capacity measurement seem to use the same basic data; there are fewer industrial firms functioning under less complex and diversified conditions than in the agricultural sector; and entrepreneurs in the nonagricultural sector have greater control of productive processes and input decisions than those in the agricultural sector.

Two basic systems are used. In one system, persons directly interview individual members of firm management to obtain data on capacity, capacity utilization rates, and desired (preferred) capacity utilization. In the other system, secondary data from various Government agencies are used. Sometimes both systems are used. Before describing these methods and systems, two additional definitions are presented.

Capacity utilization rate (operating rate) is the ratio of output of the firm to capacity at a given instant in time. If *engineering* capacity is the denominator, and if such capacity means total physical use of all fixed factors, the capacity utilization rate can never exceed 100 percent. If, however, *economic* capacity is the denominator, capacity utilization may exceed 100 percent; it would be possible for a firm to operate on the upswing of the average cost curve and not have exhausted physical capacity.

Desired capacity utilization rate is the operating rate of a firm which corresponds to management's policy framework concerning profit, the satisfaction of various members of the coalition comprising the firm, and other considerations.

The McGraw-Hill Measurement of Manufacturing Capacity Utilization. McGraw-Hill relies heavily on direct survey data. A number of business firms, representing about 63 percent of total fixed assets of all business firms (1974) and located in 20 industries, are surveyed annually. These firms are not randomly chosen; they encompass the largest firms with well-advised management willing to respond to the mail questionnaire.

Two major indexes are constructed by McGraw-Hill—one, of changes in capacity utilization rates and the other, of changes in capacity of firms, industries, and the total manufacturing sector. Two distinct sets of capacity utilization data are generated from the surveys (*12*). One covers annual changes as of December of each year; the other measures monthly changes.

The annual survey is conducted in the spring. McGraw-Hill requests three types of data:

- Information on the percentage of output relative to the firm's capacity during the previous year. (Economic capacity is implied.)
- Desired (preferred) capacity utilization.
- Information on capacity changes based on net changes in capital stock.

Information from the firms is aggregated into industry data through use of employment weights. Analysts use value-added weights derived from the 1967 Federal Reserve Board Index of Industrial Production (IP) to combine the 20 industries into major industry groups, such as durable and nondurable goods, and into total output.

For estimates of monthly capacity utilization, McGraw-Hill uses the spring survey responses on expected changes in net capacity. These changes are prorated over the survey year on an equal 12-month basis. Again, responses by firms are combined into industry groups. Net changes in monthly capacity from the McGraw-Hill Survey are divided into the monthly production changes in the IP. The result is a monthly capacity utilization rate (operating rate) by industry. Value-added weights are applied to each industry (as in the annual survey) to estimate the total capacity utilization rate. The December operating rate serves as a benchmark for the following year's monthly operating rates.

Various revisions are made in the index derived by McGraw-Hill, to align expected capacity changes with subsequent estimates of actual capacity changes throughout the year. Revisions are also required when the IP is revised.

McGraw-Hill also develops an index of the effective operating rate. This is the ratio of the index of actual to the index of preferred operating rates.

The terms capacity, operating rate, and desired (preferred) utilization rate are never defined in McGraw-Hill questionnaires. Responses have been sharply reduced when terms are carefully defined. Strangely enough, responses to undefined terms have corresponded very well to what McGraw-Hill means by these terms. Management appears to know intuitively the meaning of capacity, operating rates, and desired (preferred) capacity rates. Respondents generally appear to apply the concept of optimal (profit maximizing) performance in their response on preferred operating rates.

The McGraw-Hill series has a number of drawbacks. The indexes are not analytic. They report *ex post facto* conditions, although they can be used to predict capacity growth. They depend on opinions and estimates by the management of a limited number of large firms, although these are well-educated guesses based on years of experience. And, McGraw-Hill does not clearly define capacity. As Gift states, "... They work under the conviction that a large response to a vague question is more useful than a small response to a precise question, especially since the sample is not done randomly from a preestimated frame ..." (*13*, p. 32).

A strength of the McGraw-Hill series is the availabili of capital expenditure intentions. Also, the series data reflect the view managers have of their firms' capacity and operating rates, which may give insight into industry behavior.

The Bureau of Economic Analysis Index. The index prepared by the Bureau of Economic Analysis (BEA), U.S. Department of Commerce, covers manufacturing firms primarily. The Bureau surveys a panel of 2,400 manufacturing firms. The survey represents 75 percent of gross depreciable assets held by all manufacturers as of 1969 (*19*). Firms are asked to give capacity utilization and the desired (preferred) operating rate.

Here, the similarity between the BEA and McGraw-Hill systems ends. The BEA Survey has been quarterly since 1968. It categorizes firms into durable and nondurable goods manufacturers. It places them into three asset size classes: $100.0 million or more; $10.0 million to $99.9 million; and less than $10 million. The survey is part of a continuing BEA program which provides series on actual and expected plant and equipment expenditures, carryovers, and new investments.

Estimates of capacity utilization rates depend on calculations in which company capacity outputs are used as weights for combining firms into industry groups. Three steps are followed: First, individual company capacity utilization rates are combined to estimate rates by the 25 industries and by the 3 asset size classes; second, utilization rates of the 3 asset size classes are combined to obtain industry rates; third, industy rates are combined to obtain rates of industry groups.

The BEA indexes provide researchers with historical capacity utilization rates in manufacturing firms. For example, utilization rates were higher before 1969 than after. The indexes describe the peaks and troughs of utilization rates, and they identify groups of industries that had higher or lower levels of capacity utilization than other industries did. The indexes are a source of estimates of the correlation between size of firm and capacity utilization; larger firms had consistently higher utilization rates than medium-sized and smaller firms.

The BEA system allows tracing of total capacity development and it indicates the relationship between growth and capacity. Industries with lower than average utilization rates showed lower than average capacity increases over time. There have been, however, some notable exceptions to this rule, and no causality was established. The indexes demonstrate that preferred (desired) operating rates have been considerably higher than the actual rates. Thus, the effective utilization rate (ratio of actual to preferred capacity utilization rates) has been relatively small. These rates foreshadow desires by firms or industries to increase or decrease their assets. A high effective operating rate indicates that firms do not want added investment in new equipment, that output will not be raised until (or unless) product prices become more favorable. BEA investigators have discerned that the extent to which high operating rates induce plant expansion differs among industries and industry groups.

The Wharton School Index. The Wharton School system does not involve a survey. Its conclusions are entirely inferential. It is based on the contention that capacity is

> . . . the maximum sustainable level of output the industry can attain within a very short time if the demand for its product were not a constraining factor when the industry is operating its existing stock of capital at its customary level of intensity (*25*, p. 2).

This is an engineering definition of capacity, conditional on customary operations and independent of demand. It is measured in the short run (no fixed factor changes), and it lacks economic indicators (such as cost, profit, investment rate, and so on).

Monthly outputs from the Federal Reserve Board (FRB) index for each industry are combined by quarter. They are plotted on large graphs, and peak quarters are connected linearly. Formation of a peak quarter, when production in the preceding and following quarters is lower, is interpreted to imply achievement of a maximum sustainable output with existing equipment. A 100-percent capacity level is ascribed to each peak. The line connecting peaks denotes "full capacity." Extended like a trend line past the last peak, this line is continually adjusted with new data. The distance between the capacity trend line and the points representing actual production measures unused capacity.

This approach is a rather easy approximation of capacity utilization. However, it is more useful for historical than current measures. Continued adjustment of the capacity line may cause a low current estimate of capacity utilization to be readjusted to a high level in some subsequent quarter. An historical view may provide a quite different result than current measurements. There are some questions as to whether a straight-line interpolation is better than a curvilinear function. Adams and Summers contend that other factors, such as increasing nonproductive investments, distort the picture sufficiently to make a straight-line interpolation as applicable as any (*1*).

The Wharton Index consisted at first of 30 components of the FRB Industrial Production Index, representing manufacturing, mining, and utilities. More recently, six service industries were included (rails, airlines, trucking, residential housing, offices, and hotels).

To obtain capacity utilization in the whole industrial sector, a weighting system is applied to each industry, one that involves the estimated proportionate contribution of each industry to total national income at full employment. These proportions are estimated for quarters when the economy was operating close to full employment and they are interpolated linearly for quarters in between.

The Wharton Capacity Index has strongly deviated, particularly since 1966, from the other capacity indexes, and it shows significantly higher capacity utilization rates (*27*). As a rough approximation used in conjunction with other data, the Wharton Index has merits. However, it appears subject to considerable errors in the long run. Some alternative systems suggested by Klein are designed to be more analytic, but they also have some serious drawbacks (*20*).

The Federal Reserve Board Index of Capacity Utilization. There are two basic parts to the FRB Index of Capacity Utilization. One involves 15 materials industries (iron, steel, lumber, and so on); the other, primarily manufacturing. For materials industries, December production data are collected from industry sources. Where available, year-end data on physical capacity of the engineering type, are collected from the Government and from trade associations. These data are used to estimate physical quantity of potential output (operations largely on a 24-hour basis with adjustment for downtime, repairs, and other short term stoppages). The ratio of actual December production to December capacity yields the preliminary utilization rates. Data are weighted by value-added figures for combination into industry groups. The ratio of the Federal Reserve Industrial Production Index for December to the preliminary utilization index is then calculated. The result, the capacity index, is interpolated linearly into a quarterly index. The ratio of the quarterly FRB Industry Production Index to the quarterly capacity index yields the seasonally adjusted quarterly materials capacity utilization index.

This relatively simple measure largely treats trade information directly. However, capacity information is extremely scarce and difficult to obtain. The measure is incomplete, although it does touch on the major materials (basic processed products) of the economy.

The second FRB index reviewed is concerned primarily with manufacturing. It is based on the concept that biases in one index can be mitigated by biases in another. The manufacturing index uses: (1) estimates of fixed capital stock made by the BEA, U.S. Department of Commerce, (2) the McGraw-Hill manufacturing capacity index, and (3) the ratio of the FRB Industrial Production Index to the McGraw-Hill capacity utilization index. This ratio is designated as the derived capacity.

It is assumed that the BEA and McGraw-Hill manufacturing indexes tend to drift away from the desired measurement because of differences in weighting methods, sample biases, varied assessments of capital stock size, and changes in rates of obsolescence and depreciation. A set of time series with the adjusted derived capacity as the dependent variable is used to correct for this drift.

The two capacity measures of the Federal Reserve Board are rather crude and, because they lack sufficient information, incomplete. Yet De Leeuw was able to derive from them a number of interesting characteristics. He determined a correlation between relative material prices and capacity utilization (*8*, p. 126). He found that, after a 90-percent capacity utilization rate was reached, a sharply increasing positive relationship with materials prices prevailed. Materials prices were deflated by final product prices. He showed that capacity utilization cycles preceded investment cycles by 1 year. De Leeuw concluded that "we have good reason for supposing that capacity influences prices, costs, and fixed investment . . ." (*8*, p. 131).

National Industrial Conference Board Capacity Measurement

The method of the National Industrial Conference Board incorporates the relationship of the capital stock of a firm to capacity utilization. It is based largely on the definition of capacity given by A. Phillips (*28*). A range of outputs in an industry can be produced with given capital; no capital is added due to output variation within this range. At a certain level of output, however, there will be a tendency to purchase more capital goods. It is this level which Phillips considers the capacity of the industry.

The Conference Board develops a ratio of available fixed capital (in constant dollars) to industry output at a cyclical peak, when it is assumed that full capacity has been attained. This point becomes a benchmark. A subsequent increase in the fixed capital-output ratio relative to the benchmark year indicates excess capacity. Conversely, overutilization would be indicated by a ratio lower than the benchmark.

A problem with this method arises in the measurement of fixed capital. The Conference Board index relies on balance sheet data to obtain estimates of net capital stock. These data may be biased by inflationary impact, inadequate depreciation rates, inventory valuations, or technological differences which cannot be expressed in monetary terms (for example, a new piece of equipment costing 50 percent more than the one it replaces may be 100 percent more efficient).

The above discussion summarizes the prominent capacity and capacity utilization measurements in the nonagricultural sector. Other measurements, which are based on highly theoretical assumptions and have found little practical use, are discussed briefly in the next section.

OTHER METHODS OF DETERMINING CAPACITY AND CAPACITY UTILIZATION

There are other methods one can use to determine capacity and capacity utilization, methods based on hypotheses not yet discussed. Two such methods appear below; they remain experimental and have not been used to construct continuing indexes.

An interesting system which promises eventual implementation is that developed by Hickman (*20*). It assumes that real net investment by a firm is proportional to the difference between actual and desired capital stock levels

Capacity levels are inferred from investment behavior, or capital stock changes, of firms.

Real net investment is the change in real net capital stock over time. The desired capital stock is what would exist in a longrun equilibrium wherein the ratio of marginal physical product of capital to the price of capital equals the ratio of the marginal physical product of any other input to the price of that input.

Hickman postulates that capacity is a cost concept; it depends on capital stock, technique, and resource prices. He defines capacity as being at that point where the average cost curve is lowest. At this output, the existing capital stock is equivalent to the desired stock. Any increase in production will elicit a proportional increase in capital stock. Similarly, changes in production costs, as well as in technology, will directly affect capital stock. Given the existing capital stock, the real price of capital, and existing technology, optimal (capacity) output may be determined. Capacity is a function of relative prices and time. Hickman claims this method requires neither a production nor a cost function for capacity measurement.

The concept that net investment is proportional to the excess of actual over desired capital stock has been exchanged with the concept that net investment is proportional to the excess of "normal" over optimal (capacity) output. Since capacity is set at the point of minimum average cost, the derived economic utilization rates may exceed 100 percent. This method allows projections of capacity growth associated with different rates of capital formation. It requires a regression equation wherein net investment is the dependent variable, and output and relative prices, the independent variables. Data are required covering capital stock, output, product prices, capital goods prices, interest, depreciation rates, and wage rates. Capacity output is applied to "normal" output (the weighted average of current and recent outputs) to obtain the "normal" utilization rates of an industry.

Hickman compared his results with those obtained from other systems, some of which were reviewed above. He found that those systems using capital levels and changes as main components fit more closely to his than did the others. There are no great differences in changes of capacity between his and most of the other indexes. His capacity utilization measures exceed 100, in most cases, while the others do not. His deviations from both the McGraw-Hill and Wharton indexes appear to be quite large.

Information on the desired (equilibrium) capital stock would be quite difficult to obtain. Aggregation problems associated with Hickman's system would be complex. However, improved research on the relationship of capital stock changes to output may well lead to greater applicability of his method.

Klein and Preston use the production function approach in capacity utilization measurement (*24*). They start with a Cobb-Douglas production function whose main elements are: (1) currently employed labor, (2) currently utilized capital, and (3) technological change. Full capacity output is defined as a function of full employment of labor and capital. To satisfy the least-cost equilibrium condition, the rate of marginal substitution of capital for labor is equated to the ratio of capital returns to wage rates. To derive capacity output, the substitution rate is introduced as a coefficient to current capital in a regression analysis. The dependent variable is output and the second independent variable is current labor use. Thus, suitable adjustment of the capital stock determines capacity. Capacity utilization rates are established by the ratio of the observed output to computed output.

Some of the major problems are associated with the complexity of determining the size of currently utilized capital stock and currently employed labor. These difficulties would be particularly aggravating in the agricultural sector. Problems arise with the valuation of wages and returns to investment. Not only public policy but also the mixing of labor and entrepreneurial income in the agricultural data cause serious empirical problems. Nevertheless, the Klein-Preston method is promising.

COMPARATIVE EVALUATION OF EXISTING CAPACITY MEASURES

Capacity measurements in the agricultural sector are not based on a clearly defined concept. They represent longrun market equilibrium positions. They reflect highly divergent assumptions. They have diverse outcomes. A more careful definition and more consistent assumptions will be required to construct a reliable index of agricultural capacity.

Capacity measurements in the nonagricultural sector are based on more consistent assumptions and a clearer definition. They show less divergence than in the agricultural sector. However, George Perry finds that nonagricultural capacity estimates have shown increasing disagreement since 1966 (*27*, pp. 718-21). The following table shows Perry's pertinent capacity utilization data for four indexes for 1966 and 1969:

Comparative capacity utilization rate indexes, nonagricultural sector, 1966 and 1969

Index	1966	1969
Wharton School	96.1	96.2
McGraw-Hill capacity utilization	90.0	85.8
McGraw-Hill capacity	91.5	87.3
Federal Reserve Board capacity utilization	92.3	87.1

Source: (*27*, p. 715).

These divergences are partly caused by capital acquisition induced by accelerated wage increases and increased foreign competition. The capacity measurement methods cannot readily cope with such exigencies.

To determine the ability of three of the indexes (McGraw-Hill capacity index, McGraw-Hill capacity utilization index, and Wharton index) to predict changes in three factors—capacity, real investment levels, and prices—Perry developed regression equations (*27*, pp. 723-33). The three factors were dependent variables and the three indexes were included among the independent variables. Both McGraw-Hill indexes did quite well in predicting growth in capacity; the Wharton index did not. All three indexes proved usable for predicting levels of investment, but the Wharton index gave the weakest results. All three indexes predicted prices quite well.

Biases in the capacity utilization rate index due to capital obsolescence, changes in capital-labor ratios, and changes in technology are avoided when responses by experts in management, as in the McGraw-Hill survey, take such changes into account.

Perry found the following:

- The FRB capacity index seems to have drifted away from its early benchmark and it has shown some considerable errors (10 percent in 1973).
- The other three indexes studied can help to describe the effects that capacity utilization rates have on investment and price levels. They are less useful in predicting capacity utilization rates (except for the McGraw-Hill capacity utilization index).
- The Wharton index cannot distinguish utilization intensities at peaks in the Federal Reserve Board Index of Industrial Production. Problems with the Wharton index are associated with the frequent adjustments as new data are generated.
- In the test of the most price-sensitive industries, the McGraw-Hill capacity utilization index appears to give better indications than the Wharton index. The McGraw-Hill index shows that operating rates were considerably lower in the 1973 quarters than in the 1966 quarters, but close to the 1969 quarters when inflationary pressures began, the Wharton index shows little difference.
- The McGraw-Hill capacity utilization index appears to be the most useful of the four indexes examined.

CONCLUSIONS

A review of the literature on capacity measurement in the agricultural sector shows considerable diversity in analysis and predictions. These divergencies are partly due to an insufficiently cohesive definition of the term capacity and to the plethora of assumptions. An additional reason appears to be the lack of the "right" kind of information. Brandow states.

> Anyone seeking to make estimates of how much the U.S. could increase its agricultural production under strong incentives for more output will be impressed by how little solid information is available on the subject . . . (*3*, p. 1100).

He further submits:

> . . . we do not know much about the economic barriers to cropping all the land considered available according to soil conservation criteria, nor do we know clearly the net addition to output to be realized by cropping the land . . . .

It is clear that an information base suitable for capacity measurement should be developed.

For the nonagricultural sector, while definitions of the terms and methods employed in measurements are also divergent, there is more agreement on a definition. In addition, data from both primary and secondary sources have been developed on which to base continuing indexes. Despite the divergence that exists in definitions and methods, values of capacity indexes in the nonagricultural sector are—with one exception—not very far apart from one another. Even so, they remain quite crude and research is needed to sharpen them up and improve their reliability.

Capacity measurements are strategic in several indexes (FRB wholesale price index) and econometric models (Wharton School), and they are used in many ways. Their increased use will require more information than is currently available. This question is discussed at length by Spielmann and Weeks (*31*), and it is briefly reviewed here.

Capital utilization in the agricultural sector has different characteristics than in the nonagricultural sector. Industrial capital equipment is normally quite specific to the industry. The manufacture of glass, for example, requires equipment exclusively suited to that purpose. Consequently, capacity as well as capacity utilization rates in the glass industry, can be readily gauged by net changes in glass manufacturing equipment.

In the agricultural sector, farm equipment is far less commodity specific. The same may be said for land and labor. Factors such as weather and disease, which have no relevance to capacity output in the nonagricultural sector, have very important and frequently uncontrollable impacts on capacity in agriculture. The complexity and variability in agricultural conditions lead to the conclusion that current econometric and statistical tools cannot help us obtain reliable capacity determination until much more, better information becomes available.

The survey methods employed by McGraw-Hill and the Bureau of Economic Analysis come closest to meeting agriculture's needs. Accuracy would be improved as information is gathered, and as both interviewers and farm managers refine questions and responses. Considerable time, experience, and effort will be required to develop a workable and useful series on agricultural capacity. Whether one of the systems reviewed above can be employed for a capacity and capacity utilization index in the agricultural sector depends on its adaptability to the special characteristics underlying agricultural economic activity.

BIBLIOGRAPHY

(1) Adams, G. and R. Summers. "The Wharton Index of Capacity Utilization: A Ten Year Prospective." *1973 Proceedings of the Business and Statistics Section*, Am. Statis. Assoc.

(2) Bowman, R. T. *Testimony in Measures of Productive Capacity*. Hearings before Subcommittee on Econ. Statis. of Joint Econ. Committee, 87th Cong., 2nd sess., 1962.

(3) Brandow, G. E. "American Agriculture's Capacity to Meet Future Demands." *Am. J. Agr. Econ.* 56:5, Dec. 1974, pp. 1,093-1,102.

(4) Cochrane, W. W. "Food, Agriculture and Rural Welfare: Policies in an Uncertain World." *Am. J. Agr. Econ.* 56:5, Dec. 1974, pp. 989-997.

(5) Creamer, D. "The Use of Capital-Output Ratios to Measure Manufacturing Capacity." *Testimony in Measures of Productive Capacity*. Hearings before Subcommittee on Econ. Statis. of Joint Econ. Committee, 87th Cong., 2nd sess., 1962.

(6) Culver, D. W. and J. C. Chai. "A View of Food and Agriculture in 1980." *Agr. Econ. Res.* 22:3, July 1970, pp. 61-68.

(7) Dean, Joel. *Managerial Economics*. McGraw-Hill, New York, 1960.

(8) De Leeuw, F. *Testimony in Measures of Productive Capacity*. Hearings before Subcommittee on Statis. of Joint Econ. Committee, 87th Cong., 2nd sess., 1962.

(9) ______________. "The Concept of Capacity." *1961 Proceedings of the Business and Economic Statistics Section*, Am. Statis. Assoc.

(10) Edmonson, N. "Economic Productive Capacity in The Broadweaving Industry: An Approach to Measurement." *So. Econ. J.* 40:3, Jan. 1974, pp. 484-488.

(11) ______________. "Production Relations at High Levels of Capacity Utilization in The Steel Industry." *1973 Proceedings of the Business and Economic Statistics Section*, Am. Statis. Assoc., pp. 73-74.

(12) Gang, P. "Another Look At McGraw-Hill Measure of Industrial Operating Rates." *1973 Proceedings of the Business and Economic Statistics Section*, Am. Statis. Assoc.

(13) Gift, R. E., *Estimating Economic Capacity*. Univ. Ky. Press, Lexington, 1968.

(14) Greenwald, D. Testimony in *Measures of Productive Capacity*. Hearings before Subcommittee on Econ. Statis. of Joint Econ. Committee, 87th Cong., 2nd sess., 1962.

(15) Griliches, Zvi. "Estimates of The Aggregate Agricultural Production Functions From Gross Sectional Data." *J. Farm Econ.* 45:2, May 1963, pp. 419-428.

(16) Hathaway, D. E. "Food Prices and Inflation." *Brookings Papers on Econ. Activity*, Vol. 1, Brookings Inst., Wash., D.C., 1974, pp. 63-116.

(17) Heady, E. O. and L. V. Mayer. *Food Needs in Agriculture in 1980*. Vol. 1, National Advisory Commission on Food and Fiber, Wash., D.C., 1967.

(18) Heady, E. O., L. V. Mayer, and H. C. Madsen. *Future Farm Programs*. Iowa State Univ. Press, Ames, Iowa, 1972.

(19) Hertzberg, Marie P., A. R. Jacobs, and Jon E. Trevatan. "Utilization of Manufacturing Capacity 1965-73." *Surv. Current Business*, July 1974, pp. 47-57.

(20) Hickman, Bert. "A New Method of Capacity Estimation." *Am. Statis. Assoc. J.*, June 1964, pp. 529-549.

(21) Klein, Lawrence R. "Some Theoretical Issues In The Measurement of Capacity." *Econometrica*, Vol. 28, 1960.

(22) ______________. Testimony in *Measures of Productive Capacity*. Hearings before Subcommittee on Econ. Statis. of Joint Econ. Committee, 87th Cong., 2nd sess., 1962.

(23) ______________ and V. Long. "Capacity Utilization: Concept, Measurement and Recent Estimates." *Brookings Papers on Econ. Activity*, Vol. 3, Brookings Inst., Wash., D.C., 1973, pp. 743-756.

(24) ______________ and R. S. Preston. "Some New Results in The Measurement of Capacity Utilization." *Am. Econ. Rev.*, 57:1, Mar. 1967, pp. 342-348.

(25) ______________ and R. Summers. *The Wharton Index of Capacity Utilization*. Econ. Res. Unit, Dept. Econ., Wharton School of Finance, Univ. Pa., Philadelphia, 1966.

(26) Norton, J. DeWitt. "Capacity Statistics: Problems and Potentials." *Testimony in Measures of Productive Capacity*. Hearings before Subcommittee on Econ. Statis. of Joint Econ. Committee, 87th Cong., 2nd sess., 1962.

(27) Perry, G. L. "Capacity in Manufacturing." *Brookings Papers on Econ. Activity*, Vol. 3, Brookings Inst., Wash., D.C., 1973, pp. 701-742.

(28) Phillips, A. "Industrial Capacity: An Appraisal of Measures of Capacity." *Am. Econ. Rev.*, May 1963.

(29) Quance, C. L. and L. G. Tweeten. "Excess Capacity and Adjustment Potential in U.S. Agriculture." *Agr. Econ. Res.* 24:3, July 1972, pp. 57-66.

(30) Ruttan, V. and J. Sanders. "Surplus Capacity in American Agriculture." *Special Rpt. 28*, Univ. Minn., St. Paul, 1968.

(31) Spielmann, Heinz and Eldon E. Weeks. "Inventory and Critique of Estimates of U.S. Agricultural Capacity." *Am. J. Agr. Econ.*, 57:5, Dec. 1975, pp. 922-928.

(32) Tyner, F. H. and L. G. Tweeten. "Excess Capacity in U.S. Agriculture." *Agr. Econ. Res.*, Jan. 1964.

233-041 O - 77 - 2

(33) ______________ and L. G. Tweeten. "Optimal Resources Allocation in U.S. Agriculture." *Am. J. Agr. Econ.*, Aug. 1966.

(34) U.S. Department of Agriculture. "American Agriculture: Its Capacity To Produce." *The Farm Index*, 12:12, Feb. 1974.

(35) U.S. Senate. *Measures of Productive Capacity*. Report of Subcommittee on Econ. Statis. to Joint Econ. Committee, 87th Cong., 2nd sess., 1962.

(36) Walters, A. A. "Production and Cost Functions: An Econometric Survey." *Econometrica*, 31:1-2, Jan.-Apr. 1963, pp. 1-66.

IN EARLIER ISSUES

Strip coal mining is a rapidly expanding industry competing with agriculture for the use of lands that are underlain by suitable coal deposits. . . . As the industry grew and its operations removed ever-increasing areas from agricultural uses, the conflicts in the interests of the strip-coal companies and the local people became increasingly evident. . . . Lack of sufficient information and understanding about the variety of conditions under which strip coal mining is done is partially responsible for the diversity of the proposals for legislative regulation. . . .

Strip coal mining is an extractive industry which will probably continue as long as suitable coal deposits exist. It is increasingly recognized by both companies and citizens that the industry has an obligation, however, to help so far as possible to minimize the effects of its operations on the people in the communities in which it operates. It is of importance not only to the local people and the coal companies but to the general public as well that the stripped lands be returned to an economically sound and productive use after mining operations cease. Society has the ability through legislation to protect the interests of any individuals or the public as a whole if future research discloses such need.

George H. Walter
Volume 1, Number 1, pp. 24, 29
January 1949

There is a . . . question . . . as to where and how workers in the Bureau will find time to write articles. However, in many instances there is need for at least a progress report well before a study is wholly completed. We believe that there is good reason why a considerable amount of such work should be published in a permanent journal rather than in mimeographed form, especially as mimeographed releases are always difficult to find once immediate interest in the subject has subsided. As a matter of fact, there are several excellent reasons why researchers and statisticians within the Bureau generally should give more rather than less time to bringing their material into some organized written form. After all, *agricultural economics work is carried on in the public interest and every researcher or statistician, regardless of his field, does have a responsibility for seeing that his material is prepared in such a way as to be readily accessible to his fellow workers and to the public.*

O. V. Wells
Volume I, Number 1, p. 2
January 1949