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# ROBERT J. GORDON'S *CONCEPT OF CAPITAL*

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Estimates of capital stock normally equate different models of capital goods by their production costs at a base date (a concept known as method 1 or $K$), not by their current marginal products (method 3, or $J$). Some economists advocate that, instead, different models be equated by the base-date costs of providing characteristics of the goods, not of the goods themselves. The characteristics selected have, however, excluded the amounts of other inputs used in the production to which the good is devoted. Hence the method does not equate capital goods by their marginal products but instead by the gross products of the capital goods together with various amounts of associated inputs. Gordon recognizes this defect and believes he has remedied it empirically, but the steps he takes are too slight to support this view. It remains impractical to construct estimates that equate goods by their marginal products.

In *The Measurement of Durable Goods Prices* Robert J. Gordon does a thorough job of ferreting out information about changes in prices of durable goods from 1947 through 1983. He uses this information to compute price indexes which are then used for several purposes, among them recomputation of the durable goods components of the Bureau of Economic Analysis series for GNP valued in constant prices and the producers' durable goods component of the business capital stock. In many respects Gordon's is an admirable study. The purpose of this note, however, is not to evaluate the study as a whole, but rather to explore the concept of capital implied by Gordon's procedures for producers' durables. For this, a bit of background is required.

To measure the capital stock, valued in constant prices, by the perpetual inventory method there are, as I have repeatedly pointed out, four conceptually different ways of treating quality change in capital goods (producers' durables and structures) when one model of a good replaces another.[1] May own preference is for the Cambridge school method, which sidesteps the problem by valuing investment in capital goods as well as other investment by the value of consumption forgone.[2] This method is not immediately pertinent to Gordon's book. However, I shall return to it. The other methods are as follows.[3]

1. *Capital goods equated by cost.* New capital goods are equated with old ones by their relative costs at a common date (or, if they are not actually produced at a common date, what their relative costs *would* be if both *were* produced at

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[1]See, e. g., Denison, 1957, pp. 215-236; 1989, pp. 28-32.

[2]Denison, 1974, pp. 133-135 and especially 1989, p. 31, footnote 21.

[3]Fuller descriptions are given in Denison, 1957, pp. 217-234 and 255-259.

a common date). The value, in base-period prices, of the stock of capital goods (before allowance for capital consumption) thus measures the amount it would have cost in the base period to produce the *actual* stock of capital goods existing in a given year (*not* its equivalent in ability to contribute to production). This is the general method that has been followed by the Bureau of Economic Analysis in the past and is still followed except (in my view) for computers.

2. *Capital goods proportional to total output.* This method derives from the assumption, often used in input-output analysis, that capital-output ratios are constant. It assumes that the capital stock and other inputs in an industry move in proportion to output. It takes no account of changes in input proportions. Hardly any one now supports the use of this method described in this way.

The measures of quantities and prices of computers that BEA introduced into the national accounts a few years ago are based on the computer's capacity to acquire, store, retrieve, process, and display information, that is to say, its gross output. They take no account of requirements for other inputs—labor, structures, paper, programs and so on—that are needed to obtain the desired output from computers. They differ from method 2 measures as the method was originally formulated in that they refer to the output of a particular process and the input of a particular machine used in that process whereas in input-output analysis method 2 has usually been applied to the total output and capital of an industry.[4] I shall refer to this procedure as modified method 2. Gordon calls "proportional change" the special case where the ratio of every input used in a process to output of the process is unchanged when industries using a producers' durable adopt a new model. It is the only situation in which modified method 2 yields the same answer as method 3.

3. *Capital equated by marginal product.* This method requires that when a new model of a capital good is introduced the effects not only on the output of the process in which it is used but also on requirements for other inputs be taken into account. New capital goods are equated with old ones by their *marginal* products. The input of a type of machine or other capital good moves like *its* contribution to output. If a new good has a marginal product twice as large as an old one, it represents twice as much capital. With capital substituting for labor, this can occur even if the capital-output ratio rises. It has been, and remains, my stated belief that it is impractical to apply this third method to capital goods in general. However, it is obvious that series for the purchases or stock of capital goods measured in constant prices must rise more rapidly if method 3 is used than if method 1 is followed. Capital goods are constantly being changed, and this would not occur if, in at least some uses, the marginal product of the newer goods did not exceed that of the older goods by more than their extra cost.

Two developments in economic literature during the last decade or so have complicated the discussion of these concepts.

One, in which Gordon follows the lead of Jack Triplett, is reformulation of the descriptions of methods 1 and 3 to make them refer to characteristics of goods rather than to the goods themselves. This does not alter measurement by

[4]I disregard the complication that, when the method is implemented by correlation analysis, the coefficients in such a regression may not imply exact proportionality between the output of a process and the input of the particular machine.

method 3; the original description's requirement that capital goods be equated by their marginal products implies consideration of all of their characteristics that affect their ability to contribute to production. The reformulation radically changes measurement by method 1, however.

The original version of method 1 states that in all years different models of a type of capital good (e.g., two models of computers or two types of trucks) are the same amount of capital, valued in constant prices, if they have the same production cost at one stated common date. In contrast, the reformulation states that, regardless of when they are produced or used, different models of a type of capital good are the same amount of capital if they have equivalent performance characteristics (i.e., the same marginal product).[5] It often is obvious that it would be cheaper to replicate the newest existing factory that produces a stated product than to replicate, at the same cost per factory, factories of older designs in numbers sufficient to provide a combined marginal product equal to that of the newest factory. Several factories produced in earlier years would then equal one factory produced in the latest year according to modified method 1, whereas the factories would be equated on a one-to-one basis according to the original method 1. The situation is the same for any type of capital good that has been improved so that obsolescence has occurred. In consequence, if this reformulated concept of method 1 could be implemented, it would yield a very different result than the original concept; constant price series for the production or stock of capital goods would rise much more rapidly.

Triplett, whose 1983 article is the definitive statement of the reformulated concept, makes a sharp conceptual distinction between characteristics of a capital good that affect its production cost (and hence are relevant to reformulated method 1) and characteristics that affect its value to the user (and hence are relevant to reformulated method 3). But he explains that in practice the relevant characteristics and their price tags are nearly always (though not necessarily) the same for the two measures so that it makes little difference empirically whether indexes are based on one set of characteristics or the other. Thus the reformulation of method 1 almost eliminates any difference from method 3; if an analyst fully accounted every year for all the characteristics of a capital good that affect its cost, in every year he ordinarily would be equating different models of capital goods by their marginal products. For durable goods, Gordon finds only one difference between the two concepts, an example drawn from Triplett; he believes the presence of anti-pollution devices on cars is a characteristic relevant to method 1 because the devices add to cost but not relevant to method 3 because the devices do not increase the marginal product of business-used cars or the marginal utility of consumer-used cars. It is the reformulation of method 1 to correspond to method 3 that makes it possible for Gordon to argue that, apart from anti-pollution devices, methods 1 and 3 are the same. Of course they are, for he is simply saying that method 3 is the same as method 3.

Gordon is quite explicit that he wants to use characteristics instead of goods for both measures and that, apart from antipollution devices, the same

[5]In Triplett's language, they are equivalent in what he calls "output" characteristics where an "output" characteristic for computers (for example) is some attribute of the computer that is costly to produce.

characteristics are pertinent to both. He states (p. 17) that, apart from anti-pollution devices, "in the deflation of durable goods, the proper criterion for quality adjustment is to consider as identical two different items if their ability to produce services for consumers, or their ability to generate net revenue for producers at a fixed set of output and variable input prices, is identical. Leaving aside changes in energy efficiency and repair frequency, there is no difference in principle between deflation based on equating goods in terms of their ability to generate net revenue and deflation based on equating goods in terms of their cost, "*as long as both concepts are measured for the same units, for example, the ability of a computer to perform calculations*" (italics mine).[6] I shall comment shortly on the phrase beginning "leaving aside," but it can be ignored for the moment.

The second development that has complicated discussion is the erroneous redefinition by certain writers of the marginal product of a machine or other capital good. "Marginal product" is made to refer to the change in the *total* value added in the process in which a producers' durable is used even if quantities of any or all other inputs change, whereas it should refer to the change in value added *minus* the change in costs of inputs other than the producers' durable.[7] Perhaps in order to stress the difference between these writers and himself, Gordon also uses this faulty terminology (p. 4) and this is why he had to leave aside energy efficiency and repair frequency in the earlier quotation. However, his concept comes out right in the end. "I take seriously the old economic idea that capital goods are valued by their marginal products and extend it slightly to valuation by contribution to a firm's net revenue, that is, revenue less operating costs. Two capital goods are equivalent if they earn the same net revenue . . . ." However, the very essence of the idea of marginal products requires taking account of (deducting) all costs (or holding other input unchanged). I have always used marginal product this way in discussing quality change in capital goods and so has standard economic theory; doing so is not *extending* the definition of marginal product but *implementing* it. Nor is the "extension" slight; it is major and fundamental.

Gordon omits depreciation from the operating costs that are to be deducted in calculating net revenue.[8] I must therefore note—even though this is a distraction from the main strand of my discussion— that for three reasons not only all operating costs but also depreciation must be deducted in computing net revenue to compare marginal products. First, a change in a producers' durable may (and often does) change requirements for structures and perhaps for other types of producers' durables as well. Second, depreciation may differ among models of the type of durable good under consideration; a machine that is identical to another in every respect except that it has a longer service life and therefore less

[6]See Kuznets, 1957, pp. 275–276, and Denison, 1957, pp. 283–284, for an earlier discussion of the contention that methods 1 and 3 are the same.

[7]This change usually is not made explicit. It has come about mainly because analysts have simply ignored other inputs in both estimation and textual discussion when price and quantity estimates for capital goods are presented or discussed.

[8]That Gordon excludes depreciation from operating costs is stated most clearly on p. 76 and on p. 177, where he says "net revenue" . . . is . . . "the amount available for depreciation, interest, and before-tax profit."

depreciation each year is a better machine by the marginal productivity criterion. Third, failure to deduce depreciation causes overstatement of the *level* of net revenue; this causes understatement of the percentage change in net revenue, and hence in the price index for producers' durables, that results from the estimated absolute dollar value of an improvement in any of the characteristics of durables.

Curiously, Gordon himself is aware of at least the first two of these consequences and elsewhere in his book considers that his failure to allow for them biases his price indexes. Thus Gordon includes in a long list (pp. 38–39) of documented changes in quality that should have been allowed for in his estimates, but were not, greatly increased service lifetimes of jet aircraft relative to the piston aircraft that they replaced; a tripling of service lifetimes of automotive diesel engines between 1945 and 1975; reduced space and air conditioning requirements of electronic computers, photo-copying machines, and other electronic products; a shift from metal to plastic on many products, which reduces weight and [Gordon asserts] increases service lifetime; and reduction of weight and bulk of room air conditioners. On page 403 Gordon adds that " . . . electronic switching equipment has made possible radical reductions in equipment space occupied per line served, thus allowing many telephone companies to eliminate whole multi-story buildings that would have been required with the previous technology . . . ."

Recent writers tend to consider estimates corresponding to method 3 to be the proper goal of price and output measurement. However, before Gordon's new book all comprehensive estimates and almost all estimates for individual capital goods corresponded to method 1 as originally formulated or, if an attempt was made to move from cost to performance characteristics, ignored inputs and thus were akin to modified method 2. The latter is the case with BEA's computer price index. Implicit redefinition of method 3 by ignoring the need to consider inputs eliminates some of the method's worst complexities and thus helps to make it possible to argue that a method 3 solution is feasible. (Describing method 3 as being empirically equivalent to method 1 also made it possible to argue that the index for computers conformed to method 1 and thus was consistent with other BEA price indexes).[9]

*The Measurement of Durable Goods Prices* is the first empirical study that starts with the explicit objective of equating capital goods by their marginal products defined correctly (aside from treatment of depreciation). Despite his misuse of "marginal product," Gordon's theoretical description makes clear that estimates should take account of inputs other than the capital good under consideration. For some products Gordon actually introduces an allowance for differences between models in the cost of two other inputs—namely, fuel and maintenance costs. The allowance for differences among models in fuel efficiency is made for aircraft, automobiles, railroad equipment, TV sets, and "almost all" major appliances. Much of the total outlay for these products is made by consumers. After elimination of purchases by consumers, the remainder of these categories represented about one-sixth of the value of producers' durable goods

[9]See especially Young, 1989, Part 1.

in 1967.[10] (The share of energy saving was presumably larger.) An allowance for differences in maintenance costs is made only for TV sets, almost entirely a consumer good; this has some effect on Gordon's capital goods prices inasmuch as TV experience is introduced to infer changes in characteristics of business purchases of electronic equipment (p. 407).[11] In every case in which an allowance is made for these costs the change in the product is favorable, i.e., the newer model is more energy efficient or requires less maintenance per unit of quality-adjusted output—and, I think even per machine or other durable good. Gordon does not state the total effect of differences between models in energy and maintenance costs upon his price indexes for producers' durables or consumer durables. However, his discussions of individual products suggest that the aggregate amounts are sizable, so that ignoring these costs would have introduced a substantial upward bias into the price indexes.[12]

Gordon does not point out that the energy and maintenance costs he measures are a very small part (perhaps two percent) of total factor costs and inter-industry purchases in the industries in which producers' durables are used, which include all industries in the business sector.[13]

Gordon recognizes in the theoretical sections of his general chapters, which cover pp. 3–107, that differences among models in all costs associated with the use of durables should be brought into the calculation. However, in the more empirical portions of these chapters he consistently writes as if fuel and repair costs were the only costs that require attention (i.e., p. 4, which I have already quoted, and pp. 14, 17, 19, 20, 41, 43, 107). Nevertheless, Gordon has told me that differences in crew costs actually are taken into account in his comparisons of the costs of using different models of commercial aircraft. Thus, he allowed for the difference between requirements for three pilots by the B727-200 and for two pilots by the DC9-80 when these aircraft were compared (Table 4.8). A specific allowance for labor requirements is also made in comparing different vintages of electric utility generating plants.

An alternative series for commercial aircraft is based on comparisons of the selling prices of used aircraft. Gordon argues (correctly if markets are perfect and, as he states is the case with aircraft, duration and mileage of previous service are of little consequence) that such prices reflect differences in all aircraft characteristics that are of interest to the buyer, including labor and other costs of operation. Gordon also examines second-hand prices of autos (many of which are used by business) and of tractors in evaluating estimates for these products.

[10]Gordon, p. 521, column 2. Aircraft, automobiles and railroad equipment represented 16.6 percent of total PDE expenditures in 1947, 16.5 percent in 1967, and 10.8 percent in 1983.

[11]Gordon summarizes his coverage of energy and repair costs on pp. 4–5.

[12]Nevertheless, Gordon says (p. 5) that most of the very large difference between BEA's price indexes and his stems not from operating cost adjustments but from "a consistent implementation of current theoretical practice," by which he means evaluating gross output characteristics while ignoring inputs.

[13]Energy costs of all industries are about two percent of total factor costs and inter-industry purchases. (See Jack Alterman, *A Historical Perspective on Changes in U.S. Energy-Output Ratios*, report by Resources for the Future to Electric Power Research Institute, Palo Alto, 1985.) The maintenance costs that Gordon covers in his calculations for *producers'* durables (for TV sets only, plus an inferred effect on electrical equipment), appear to be no larger than the energy costs he omits. Gordon erroneously calls energy a "factor cost" (p. 57) but this does not affect his computations.

These are among the used asset markets that are best suited for equating models but there are pitfalls in their use (which Gordon discusses) that have been much debated. Whatever the suitability of second-hand prices for these goods, there are few other producers' durables for which they are as suitable.

Gordon's estimates for producers' durables other than aircraft and electric utility generating plants make no specific adjustment for differences in requirements for labor, structures, inventories, land, or purchased materials or services. Gordon performs a useful service by stating explicitly on pages 62–63 the assumption that is implied when labor requirements are omitted from a comparison. It is that the ratio of labor costs incurred to operate a producers' durable to the gross output of the durable is the same for successive models of a type of durable. In this formulation gross output must be measured after full adjustment for quality change in the durable, excluding effects on other inputs. Thus, since Gordon finds that a 1984 computer processor turned out 1,337 times as much as a 1951 computer processor with the same nominal price, he is assuming that it required 1,337 times as much labor to operate it.[14] Requirements for structures, inventories, land, and purchased materials and services are also assumed to be 1,337 times as great in 1984 as in 1951. If the newer computer processor required less than 1,337 times as much of these inputs, then Gordon's price index for computer processors is biased upward over time, probably by a huge amount. (This statement assumes that the index correctly measures the price of computer characteristics other than the use of inputs.)

A hypothesis may be suggested as to why Gordon may have felt that labor requirements often could be ignored in measuring capital by method 3. In many, perhaps most, business enterprises one person typically mans each piece of equipment or each work station. One worker may continue to do so when equipment is improved to allow more units of output to be obtained or the quality of output to be raised. This seeming stability in labor requirements could easily lead one to suppose that changes in requirements for labor can be ignored. This is typically quite wrong, even if rarely so dramatically off the mark as in the case of the computer. In implementing method 3, labor associated with the use of producers' durables could be ignored only if requirements for labor increased in proportion to *quality-adjusted output.* The same is true of requirements for structures, materials, and other inputs. Such a proportional increase in inputs is usually implausible, except perhaps for materials, when the increase in output consists of more units and even more implausible when the increase in output consists of improvements in its quality. Ignoring such inputs is to understate the increase over time in the quantity of producers' durable goods and overstate the increase in their price, as quantities and prices are defined by method 3 (and by restated method 1).

It must also be pointed out that, in considering the effect of a new model on labor per unit of output, it is not sufficient just to consider labor directly involved in the process in which the category of producers' durable under consideration is used. Thus, a reduction in the number of workers per unit of

[14]Gordon, Table 6.7, pp. 213–214, shows his final price index for computer processors falling from 133,666 to 100 in this period.

output in this process normally would also reduce the need, per unit of the same output, for labor assigned to functions such as management, the personnel department, and accounting—and for sales as well if the increase in output consists of quality improvement. Per unit of the same output, it would also reduce requirements in these functions for space, furniture, equipment, supplies, lighting, and other inputs that are related to the number of persons employed.

It is sometimes suggested that costs of characteristics of producers' durables that affect their purchasers' costs of inputs may be so highly correlated with characteristics that affect the gross output of the processes in which the durables are used that a hedonic function that uses the latter characteristics as independent variables will take account of input requirements. Even if in some cases this happened to be so, there still would be no reason to suppose a similar close correlation exists with respect to changes that occur over time in the two types of characteristics—beyond the presumption that both have tended to improve.

Gordon occasionally mentions the omission of labor from his calculations for individual products. Thus he says (p. 112) that the introduction of jet aircraft reduced crew costs because jets produce many more seat miles per crew member than did the piston engine planes they replaced. A new PBX system saves 75 percent of operator costs (p. 406). Account needs to be taken of the lower level of skills needed by operators of the newer machine tools (p. 463). No attention has been given to the saving in time made possible by the replacement of the rotary calculating machine by electronic calculators (p. 96). However, Gordon seems not to realize the enormous potential importance of his omission of most labor and the remaining factor inputs and interindustry purchases from the calculation when he measures price changes.

I do not suggest that Gordon's price index for *all* producers durables are necessarily biased upward when viewed as method 3 estimates. The error can be downward, especially, it would seem, when there is little improvement in output characteristics of a durable and an innovation involves substituting labor, structures, or materials for producers' durables. However, I do not find it easy to think of realistic examples of downward bias and it seems certain that failure to account for inputs biases Gordon's comprehensive price indexes sharply upward compared to what the marginal product criterion requires.[15]

This should not surprise analysts who believe most "technical progress' is "embodied" in producers' durables.[16] Given the small weight of producers' durables in total input (about 5 percent), if these analysts happen to be correct the increase in the constant-price value of the marginal-product equated stock of producers' durables from 1947 to 1983 would have to be far greater than Gordon's estimates show. This would imply a sharp decline in marginal-product-equated producers' durable goods prices.

However this may be, what is certain is that Gordon's price series are concerned with such a small part of the costs of the users of producers' durables that they cannot reasonably be described as based on the equating of different

[15]Gordon believes his indexes are biased upward even without considering omitted inputs.

[16]The importance of producers' durables in embodiment is stressed by T.P. Hill, 1964, and by J. Bradford De Long and Lawrence H. Summers, 1990.

models by their marginal products. They are, in fact, a mixture of original method 1 and modified method 2 estimates with a small gesture toward method 3. There is no reason to suppose that they approximate the results that would be obtained if method 3 could be applied comprehensively.

For many years I have insisted that it is not possible to derive comprehensive constant-price measures of the output of capital goods and the capital stock that equate capital goods by their marginal products. A main purpose of this paper is to point out that Gordon's book does not challenge this belief. Decades of careful research enabled Gordon to institute methodology that appears to improve considerably estimates defined as corresponding to original method 1, but to make only meager progress in moving estimates toward the method 3 concept.[17] Hedonic techniques using both output characteristics and input requirements of the process in which a durable is used have been suggested as a way to do so. However, Gordon's experience in trying to use hedonic techniques to incorporate into his series even half a dozen characteristics of a durable good led him to conclude that it was generally impractical to handle more than a small number of characteristics because of multicollinearity and of quality changes that occur in all models simultaneously and hence cannot be identified in a cross-sectional regression equation (p. 18).[18] This is in addition to the overwhelming problem of tracking changes over time in all pertinent characteristics. A full accounting would often require handling scores of output *and* cost characteristics. Gordon's investigation uncovered large gaps in information even for the characteristics he attempted to measure.

A complete list of problems in measuring the output of producers' durables in ways consistent with method 3 would be daunting. There is the problem of comparing gross output characteristics of different models in such a way as to identify, measure, and value all differences in such characteristics that are pertinent to a buyer's evaluation of the product. There is the problem of identifying, measuring, and valuing differences between models in the amounts of all types of labour and all other factor inputs that are used anywhere in the operation of the firm using the producers' durable. Unless differences between models in requirements for purchased materials and services are accounted for fully, which they never are, it becomes necessary to trace the effect of a new model in the amount of labor and other inputs required by suppliers of such materials and services to firms using the new model, and on the requirements of their suppliers. There are "downstream" as well as these "upstream" problems. For example, a new vintage of oil furnace may be more fuel efficient, more reliable, longer lasting and better able to maintain a constant temperature in a building than its predecessor, and thus be counted as 30 percent more product when sold by the manufacturer, the wholesaler, and the retailer, or shipped by a transportation firm. However, it may be no larger or heavier than its predecessor and require

[17]I do not wish to appraise in detail the adjustments for quality that Gordon *does* make, but note that he himself insists they are insufficient and understate the amount of quality improvement. He is also quite fair about noting the many uncertainties, contradictions, and gaps in information that qualify the adjustments he makes.

[18]Gordon notes that improvements in energy efficiency, his main example of a measured change in other input requirements, tend to be made on all models simultaneously.

the use of no more labor and other inputs by the trade and transportation firms, so that their ratios of input to quality-adjusted output in handling oil burners fall. By method 3 this should be counted at all industry levels as a drop in the quality-adjusted price of oil burners additional to the original 30 percent but no existing method of directly adjusting capital goods for changes in their characteristics would do so.

On the assumption of perfect markets and other stringent assumptions the difference between the prices of different models on second-hand markets would reflect such effects on all firms down to the last business affected, and a price comparison would obviate the need to identify and trace characteristics, but for few products are reasonably accurate comparisons possible.

Concepts for the measurement of consumer durables parallel those for producers' durables if marginal utility is substituted for marginal product. If models are to be equated by the amounts or prices of each between which consumers are indifferent, one must account not only for gross output characteristics, but also for input characteristics such as fuel consumption; maintenance expenditures; depreciation; space required when they are in use or in storage between uses; and the time of family members if their use is either a chore (vacuum cleaners) or a pleasure (sailboats). Gordon's coverage of characteristics of consumer durables is similar to that for producers' durables.

When indexes for products are combined into Tornqvist indexes for prices of producers' durables from 1947 to 1983, Gordon's series rises by 2.96 percentage points a year less than do the prices used to deflate producer's durables by the Bureau of Economic Analysis (p. 536).[19] The differences are 4.13 percentage points in 1947–60, 2.44 in 1960–73, and 2.07 in 1973–83. Gordon gives corresponding differences for consumer durables. They are 1.54 percentage points in the full 1947–83 period, 2.21 in 1947–60, 1.24 in 1960–73, and 1.05 in 1973–83.

It would be interesting to divide these differences among amounts corresponding to (a) corrections of BEA series while still following method 1 as originally formulated (equivalence of base-year price or cost of goods); (b) differences between estimates prepared according to original method 1 and to "modified" method 2; and (c) differences between modified method 2 and method 3. Computers would have to be handled separately because in my view BEA itself measures their prices by modified method 2. Almost all the information required for such an analysis of Gordon's differences from BEA estimates is apparently available from Gordon's book or worksheets.

As indicated earlier, most of Gordon's "corrections" of BEA series do not depart from the concept generally followed by BEA, which is original method 1. His arguments for most of these are appealing and merit examination in BEA's next revision of the national accounts.

Let me now try to summarize Gordon's and my views of concepts for capital goods.

I believe that, however interesting it would be to construct comprehensive estimates of output by method 3, which equates models by marginal products,

[19]The difference between products for which there are two estimates is greater than this; Gordon does not estimate indexes for some types of product and for these he uses BEA series.

it is impossible to do so. Gordon apparently believes he *has* done so. Gordon (pp. 56–58) considers our differing views on the possibility of implementing method 3 to be the main difference between us and this is probably so.

We agree that method 2, which makes capital move like output, is a useless concept. I think that Gordon also agrees with me that what I have described as a modified method 2, and he as assuming proportional change, is also unsatisfactory.

I regard method 1 as feasible.[20] I also regard it as a distinct concept and a useful one. Gordon, though in nominal agreement that it is feasible, considers it to be the same as method 3 if construed as equating goods by performance characteristics or as meaningless if it is not so construed. As pointed out earlier, to make method 1 the same as method 3 requires that it be redefined in such a way that, in years other than the base year, models of a machine having the same performance characteristics but different base-year costs be counted as the same amount of capital, which is the method 3 concept.

Where does this bring us? Suppose I were right that estimates corresponding to method 3 cannot be constructed, that Gordon and I were both right that estimates corresponding to method 2 or modified method 2 are useless, and that Gordon were right that method 1 is either the same as method 3 (if output and capital are measured by characteristics) or else a "logically inconsistent method" (p. 56).[21] By elimination, there could in that case be only one useful *and* possible

[20]Specification pricing, with linking of price indexes when specifications change, long applied in constructing the consumer price index, is the procedure most frequently used in price indexes and leads to method 1 results. (Attention to the dates at which linking takes place is sometimes important). Other procedures ordinarily used in constructing price indexes also lead to method 1; this includes the hedonic residential construction price index. Some but not all applications of the hedonic procedure, notably that used for computers, are an exception.

[21]Gordon's description of my use of original method 1 to value the deflated capital stock as "logically inconsistent" is based on an erroneous claim (Gordon, 1990, p. 57) that I treat labor and capital differently. It refers to my application of earnings weights to combine workers with different amounts of education in the measurement of labor input. Gordon's claim of inconsistency is incorrect, as I showed in the same book that Gordon cites. (See Denison, 1967, pp. 8–9.) In short, simply to count workers without regard to their relevant characteristics, such as education, in measuring labor input would be analogous to counting the number of items in the capital stock (Lincoln cars, Chevrolet's, hand lawn mowers, paint brushes, steel mills, etc.) without regard to their values, whereas in fact not their numbers but their values are added to obtain the capital stock. On the assumption that in current prices the earnings and marginal products of different capital goods are proportional to their values, measurement of capital by method 1 parallels my treatment of labor. The education indexes do not allow for the fact that society's stock of knowledge available to be taught students improves just as the capital input indexes do not allow for the fact that new knowledge permits better capital goods to be built with the same inputs. There "is no difference between the labor and capital input indexes with respect to the kinds of 'quality adjustment' for which allowance is made. Both take account of changes in composition. Neither considers an increase over time in marginal product that results from advances in technical or organizational knowledge to be an increase in input." (Denison, 1967, p. 8.) Also see T.W. Schultz (1961, p. 3), quoted in Denison, 1987, p. 572.

Gordon (1990, p. 57) also cites Simon Kuznets's discussion of my 1957 conference paper. Gordon quoted Denison (1957) as saying that improvements not involving additional cost are "usually considered" increases in output in the case of consumers' goods but, by method 1, are not so considered in the case of durable capital goods'; and that this aspect of method 1 is defensible because capital goods are instruments of production, not products desired for their own sake. Kuznets (1957, p. 275) remarked that Denison "recognizes that this brings him perilously close to Irving Fisher's position that national product should be confined to consumption." My use of the wording "usually considered" evidently misled Gordon; it means "usually regarded as," not "usually measured as"; at the same conference session I pointed out (Denison, 1957, p. 284) that in practice "price

way of handling quality change in capital goods, namely, to measure investment by consumption forgone.[22]

Consumption forgone does provide a superior measure of investment and capital stock in constant prices if, as is often the case, one's interest lies in the total values of investment and capital stock in business or the whole economy—that is, the values of structures, producers' durables, inventories, and (for the whole economy) net foreign investment. However, the method does not provide detail for investment and capital stock such that the percentage distribution of constant dollar estimates differs from that of current dollar estimates. This is usually regarded as unsatisfactory when capital is to be used as an input in measuring productivity by industry or end product.

What, then, of Gordon's dismissal of method 1, given its original interpretation, because it misclassifies the effects of certain advances in knowledge as a contribution of capital? I disagree with Gordon that this defect, which distinguishes method 1 from consumption forgone, impairs it so badly as to make it useless. By the consumption forgone method, the contribution made to growth of the national income by advances in knowledge appears as an increase in output per unit of input (and within output per unit of input as a contribution of advances in knowledge). By method 1 the same is true of most advances in knowledge. However, as I learned from Tom Rymes and stated two decades ago, and as Gordon states in *The Measurement of Durable Goods Prices* (p. 58), contributions made by advances in knowledge to the increase in the output of durable capital goods appear as a contribution of capital (and hence total input) when capital is measured by method 1.[23] Thus, by method 1, some of the contribution of advances in knowledge is misclassified as a contribution of capital.

How large is this portion? The answer obviously depends not only on the time and place under consideration but also on the accuracy of the method 1 estimates with which a series for consumption forgone is compared. Estimates for Canada by Cas and Rymes (p. 5) indicate that the 1961–80 growth rate of GNP per unit of input in the private economy is lower by 0.47 percentage points or 28 percent when method 1 is used instead of consumption forgone, and the contribution of capital is raised by the same 0.47 points. Estimates by Scott (1989) for several countries and periods yield much smaller differences. So do my rough calculations for NNP in the United States.[24] One fact may help to put the matter in perspective. In the United States net capital formation in the form of structures and equipment averages about 10 percent of business net product. The percentage of the contribution of advances in knowledge to growth that pertains to production

[22]I do not mean to imply that Gordon endorses the consumption forgone concept; a comment on his page 59 indicates that he does not. Also to be noted is that difficulties in measuring prices of consumption necessarily qualify the accuracy of a consumption forgone measure.

[23]See Rymes, 1971; Denison, 1974 and 1989 and additional citations therein to Rymes; Gordon, 1990.

[24]Denison, 1974, pp. 133–135 and 1989, pp. 30–32.

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indexes for consumer goods do not appear to capture most quality improvement not associated with corresponding cost changes." As indicated in the *present* text there is *no* difference *in principle* between consumers' and capital goods in this respect.

The most interesting aspect of Kuznets's comment was actually his tentative endorsement (see Kuznets, 1957, p. 276 and Denison, 1957, p. 284) of the use of consumption forgone to measure capital.

of capital goods would also be 10 percent if knowledge of how to produce at low cost increases as fast in capital goods production as in production of other products.[25] If the increase is larger than elsewhere the portion misclassified exceeds 10 percent, but it is surely much the smaller part of the total contribution of advances in knowledge.

One advantage of preparing estimates of the production and stock of capital goods not only by the consumption forgone procedure but also by method 1 is that different price indexes can be used to deflate different capital goods, thus obtaining series for capital stock that may be more useful for measuring capital input, and hence output per unit of input, by industry or product, and estimates of price changes that may be more useful for the study of the composition of inflation.

In weighing Gordon's objection to method 1 on the ground that the contribution of advances in knowledge is divided between input and output per unit of input, one should realize that if method 3 could be implemented, it would also divide this contribution. Advances in knowledge that are regarded as "embodied" in capital goods would be classified as raising input, whereas advances not so embodied would be classified as raising output per unit of input. Only the consumption forgone method avoids a division.

Contrary to Gordon's opinion, consistent use of method 1 for producers' and consumers' goods leads to a coherent measure of the national product. I described it with respect to consumption long ago and have often repeated the description. The principle is the same for total national product. The years, of course, are illustrative and can be updated without other changes.

"When we say on the basis of the official estimates that total real consumption increased by 112 percent from 1929 to 1957, we are comparing actual consumer purchases in 1929 with the sum of (1) products purchased in 1957 that were identical with those bought in 1929 and (2) the sum of products *not* available in 1929 valued in terms of the products that the resources used in their production *could* have provided in 1957 if used to produce the products that did exist in 1929. This is only a crude description of the estimates (which rest on a variety of sources that do not follow wholly consistent procedures), but it is approximately correct. Clearly, the estimates do not take into account either the improvements made in a great range of products without a corresponding change in their production costs, nor the vastly greater range of choice open to today's consumer. He can, if he wishes, choose to buy antibiotics that will cure his illness rather than spend the same amount on remedies that will not; to buy a television set rather than spend the same amount for radios; or to cross the continent by plane in hours rather than by train in days."[26]

I close this essay where I began. Although Gordon has not reached his unachievable goal of taking account of input and output characteristics in measuring durable goods production, his book does provide a very great amount of information that is useful for measurement of production in accordance with an attainable measurement objective.

[25]National accounts estimates imply that output per unit of input increased by a less than average amount in production of structures; see Denison, 1989, pp. 70–72.

[26]Denison, 1962, pp. 156–157.

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