THE ROLE OF VALUE ADDED IN BENEFIT/COST ANALYSIS

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A.E. Research Series No. 90-8

July 1990

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ABSTRACT. The problem is to determine the role of value-added information in obtaining a measure of the benefits of public investment. Net benefit in a benefit/cost analysis is the change in economic surplus, i.e., the sum of the increase in consumer surplus and economic rent. An increase in productivity causes an increase in economic surplus. Thus, a productivity index is necessary but not sufficient information needed to measure the change in economic surplus. Information on value added can be used to establish productivity. Diewert's quadratic lemma is used to deduce an index of productivity as the difference between indexes of value added and its primary components in the context of a non-homothetic production function. It is concluded that this same procedure should be used to measure productivity in either a taut or a slack economy.

* The author would like to thank Judith Brown and Jack Stabler for their helpful comments on earlier drafts of this article.

This research is funded, in part, by interregional research project IR-6 and the Idaho agricultural experiment station project 054-H923.

THE PROBLEM: USING VALUE-ADDED INFORMATION IN BENEFIT/COST ANALYSIS

The change in value added would seem to be an alluring way to gauge the general equilibrium benefits from a public investment project. Young and Gray list the reports using value added to measure net benefits [p. 1819]. The use and abuse of value added in benefit/cost analysis has been the focus of attention in several recent articles in the regional economics literature [3, 8, and 9]. A key question posed by the authors in each instance is whether value added is ever an acceptable measure of net benefits in a benefit/cost analysis of a publicly supported irrigation project? Another is whether the benefits in a benefit/cost analysis are measured differently when the economy under consideration is at full-employment or less-than-full-employment? The controversy focuses on benefits. Typically, the costs of a public project can be determined relatively easily and accurately, since they tend to appear ex post as an item in some government agency's budget.

In this paper, it is argued that economic surplus is the only appropriate measure of benefits for public investment.[1] However, there is still a very important role

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[1] In the literature, this point of view has also been adopted by Young and Gray and by Stabler et al.: "... the economic surplus approach developed in applied welfare

that value-added information can play in the process of determining economic surplus. Ex post, value-added information can be used to determine the change in productivity that resulted from a public investment. A productivity index is a necessary but not sufficient information for measuring economic surplus.[2] Therefore, value-added information is indirectly helpful in measuring the benefits to public investment in a full-employment or

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economics should be the guiding criterion in regional, as in national contexts" for benefit/cost analysis [9, p. 1820]; and "... value added is not a measure of benefit; it is merely the upper limit on the opportunity cost of the resources employed ..." [8, p. 16].

[2] Again, this point has been recognized, at least implicitly, by Young and Gray and by Staler et al.: "... for a water resource project to leave the region better off than it was without the investment, the value of the incremental output must exceed the sum of the opportunity costs of all resources required for the public development of the project and for the private utilization of the water" [9, 1822]. Euler's theorem would suggest that this is only possible for a linearly homogeneous production function when increases in productivity take place. Also, "the irrigation project is modelled as an outward rotation of the supply curve for agricultural products" [8, 17].

"taut" economy. It is hoped that some light can be shed on the role of value added in measuring economic surplus in the less-than-full-employment or "slack" economy as well.

THE RELATIONSHIP BETWEEN FACTOR INTENSITY AND PRODUCTIVITY

The benefits from a public investment in a sector represent a positive-sum increase in the real income, as measured by the change in economic surplus, for one or more groups of people. Given constant demand, economic surplus increases when the production of a commodity can be increased with a less than proportional increase in the quantity of inputs, i.e., increased productivity. In such cases, public investment in human and physical capital causes a rise in productivity of the sector that increases value added and economic surplus. Value added is the payment to the primary factors of capital and labor. An increase in value added, as demonstrated below, is equal to the increases in capital and labor intensity and productivity. Changes in economic surplus, on the other hand, are equal to the increases in real income to consumers and resource owners.[3] The greater the increase in productivity, the

[3] An increased payment to a primary factor may or may not include economic rent depending on the elasticity of supply of the input faced by the firm, industry, or sector. The total payment to a primary factor may increase simply because more units are needed at a given price. Economic

larger the economic surplus and the more efficient the public investment. Solow has shown that continuing growth in productivity (and continuing public investment) can result in stable growth in real income over time [p. 38].[4]

Increasing labor and/or capital intensity -- as opposed to productivity -- also increases output and value added, at

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rent refers to the situation in which the factor price on all units must be bid up in order to entice the marginal units from their employment elsewhere in the economy.

[4] Solow's neoclassical model of growth assumes that the economy is in competitive equilibrium such that there is a Pareto optimal allocation of resources, with each sector making equally productive use of the capital and labor available. It is likely, however, that there are systematic variations in the returns to labor and capital in different sectors. These variations would make it possible to increase output by reallocating capital and labor from less productive to more productive sectors. Therefore, other sources of growth in output include reallocating resources between sectors, economies of scale, and reduction of internal and external bottlenecks [1, p. 15]. In this paper, productivity is defined to include changes in total factor productivity and scale economies only. "Productivity gains" from resource allocation and reduction of bottlenecks are associated with the restructuring of a "slack" economy.

least temporarily. It can be shown that additional capital investment in a full-employment economy, without an accompanying increase in productivity, results in a temporary increase in real income only and is not a defensible justification for public investment. Increasing the rate of growth in capital investment beyond the "natural rate" i.e., the rates of growth in the labor supply and in technological change, will not result in a further increase in the rate of growth in real income in the long run [7, p. 38]. Up to the natural rate of investment, capital is needed to complement increases in the labor supply and in productivity.

Solow illustrates this phenomenon with the following "stylized facts" [pp. 23-30]. Assume there is an increase in savings and investment (or taxes and government spending) without any associated increase in productivity. Implicitly, this assumes that the additions to the stocks of physical and/or human capital are homogeneous -- just "more of the same." Assume also that, at a constant rate of unemployment, the supply of labor is fixed. Then additional capital investments increase the ratio of capital to labor, i.e., increase capital intensity. Output per worker increases and output per unit of capital decreases. The payoff is a permanently higher savings rate and a lower consumption rate per capita [7, pp. 23-24].[5] The high Japanese saving rate might make that economy an example of this phenomenon.

When technological change is included in the model, the equilibrium growth rate of savings and investment in capital expands beyond the rate of growth in the labor force and now includes the rate of growth in productivity as well.

> The natural rate of growth [in capital and output] is ... the sum of the rate of population increase and the rate of technological progress. A change in the savings rate does not change that; ... an increase in the rate of technological progress itself, besides increasing the rates of growth of output and output per head (therefore consumption per head), will also increase effective employment per unit of capital [7, p. 38].

INCREASED PRODUCTIVITY AND CHANGING ECONOMIC SURPLUS

When public investment increases productivity, it increases the marginal productivity of each input, which shifts the supply curve outward and thereby increasing

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[5] "Initially, the rate of growth of output must be higher than the steady-state rate of growth .... But eventually the economy approaches its new steady state; the rate of growth of output slows down to the rate of growth in the labor force ... [7, p. 26]. Consumption is maximized when the marginal product of capital is just equal to the rate of growth in the labor force" [7, pp. 27-28].

economic surplus. Thus, the public investment project that increase economic surplus affects different categories of people either positively and negatively. Consumers' benefit from a decrease in the commodity price, which is measured as consumer surplus. Resource owners of inputs available in less than perfectly elastic supply benefit from an increased input price, which is measured as economic rent. Economic surplus is the sum of consumer surplus and economic rent.

The groups negatively affected by an increase in productivity include those who own (or, in the case of labor, are) "saved resources" that have low opportunity costs and become underemployed elsewhere in the economy. These people experience the full fury of Schumpeter's "gales of creative destruction." The measure of economic surplus assumes saved resources are re-employed at their ex ante opportunity cost. Saved resources that are re-employed below their previous factor price represent a restructuring cost that must be addressed when estimating the change in economic surplus. In fact, there are two restructuring-of-underemployed-resources issues that need to be consistently resolved. First, there is the problem of whether to count as an additional cost, saved resources that become underemployed as a result of the public investment. Second, there is the issue of whether previously underemployed resources that are re-employed because of a given public investment should be counted as an additional benefit. Both of these problems will be discussed subsequently. For now, the assumption of a taut economy precludes both of these questions.

We need a measure of the shift in the supply curve associated with the change in productivity and a measure of the change in economic surplus associated with the change in real income. The net change in economic surplus is the measure of benefits then used in a benefit/cost calculation. To measure economic surplus ex post, as a parallel shift in the supply function, the equations suggested by Rose can be used [5, p. 834-5].

$$ES = kP_0(Q_0 + 1/2(Q_1-Q_0)), \quad (1)$$

where ES is economic surplus; k is an index of the shift in the supply curve, i.e., total factor productivity; P_0 is the initial commodity price; Q_0 is the initial commodity quantity; and Q_1 is the subsequent quantity.

Equation (1) is used to estimate economic surplus. This equation requires measures of P_0, Q_0, and Q_1 that are either known or readily determined ex post. Equation (1) also requires, not surprisingly, a measure of the shift in supply k that is associated with the change in productivity and remains to be derived.

To summarize, only economic surplus or the sum of consumer surplus and economic rent are used to measure benefits in a full-employment benefit/cost analysis. The measure of economic surplus requires a measure of the shift in supply associated with a change in productivity. Value added can be use to measure the change in total factor productivity that causes the supply shift. Value added is not a direct measure of economic surplus but it can be used as a direct measure of productivity. In the next section, the change in value added and its components will be used to measure productivity as a measure of the k shift in the supply curve needed in equation (1).

TOTAL FACTOR PRODUCTIVITY AND VALUE ADDED

Consider a continuous, twice differentiable, concave, linearly homogeneous production function for industries in a full-employment general equilibrium economy in which output is a function of primary inputs and a discrete variable for time.

$$V_i = F(K_i, L_i, T_i), \qquad (2)$$

where V is the output in terms of value added in sector i; K and L are capital and labor in sector i; and T is time used as a discrete measure of technological change.[6]

[6] Value added is a function of capital and labor only, since the inclusion of intermediate inputs would amount to double counting in a general equilibrium context [1, p. 17]. For partial equilibrium analysis, gross industrial output is a function of both primary and intermediate inputs.

Equation (2), expressed in terms of growth, is

$$G_{Vi} = G_{Ti} + S_{Ki}G_{Ki} + S_{Li}G_{Li}. \qquad (3)$$

Where G_{Vi} is the rate of growth in value added in sector i, G_{Ki} is the rate of growth in the quantity of capital, G_{Li} is the rate of growth in the quantity of labor, and G_{Ti} is the rate of growth in total factor productivity, S_{ji} is the share of value added of primary input j [1, p. 17].[7]

Solving for the growth in productivity,

$$G_{Ti} = G_{Vi} - S_{Ki}G_{Ki} - S_{Li}G_{Li}. \qquad (4)$$

Equation (4) indicates that the growth in total factor productivity equals the growth in value added less the growth in capital and labor weighted by their factor shares. Thus, the growth in value added over-estimates the growth in total factor productivity by the growth in capital and labor intensity. This result is consistent with similar conclusions reached by Young and Gray, Hamilton and Gardner, and Stabler et al.[8]

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[7] This equation is derived from a Cobb-Douglas production function.

[8] Stabler et al. state, "It is obvious ... that input-output models are poorly suited for calculating indirect benefits, properly defined. Optimally what is required is a computable general equilibrium model" [p. 13]. It is argued here that value-added information (including that found in two independently derived input-output models of a region)

Equation (4) can be expressed more generally for empirical purposes in terms of a non-homothetic production function expressed in logarithms. Diewert's quadratic lemma is then applied to determine a second-order approximation of the change in productivity as the geometric mean of V_a and V_b expanded around points in time a and b [2, p. 118]. Dropping the i subscript,

$$\tfrac{1}{2}(\alpha_a + \alpha_b)\ T_a - T_b = \ln V_a - \ln V_b - \tfrac{1}{2}(S_{Ka}+S_{Kb})\ (\ln K_a - \ln K_b) - \tfrac{1}{2}(S_{La}+S_{Lb})\ (\ln L_a - \ln L_b), \quad (5)$$

where α_t is a measure of productivity relative to time t. The information needed to estimate equation (5) includes initial and subsequent value added (V_a, V_b), quantity of capital (K_a, K_b) and labor (L_a, L_b), and factor shares of capital (S_{Ka}, S_{Kb}) and labor (S_{La}, S_{Lb}). Equation (5) measures the index of total factor productivity as the difference between the index of output and a Tornquist index of inputs, adjusted for changing factor prices [2, p. 120].[9] The left side of equation (5) is a measure of the k shift in can be used to measure the general-equilibrium supply shift as an increase in productivity that is needed to estimate benefits, both direct and indirect.

[9] This measure of total factor productivity will include the effects of changes in economies of scale since no steps have been taken to separate these two sources of productivity gain.

the supply curve referred to in equation (1) that is used to determine economic surplus.

MEASURING BENEFITS AND COSTS IN A SLACK ECONOMY

Is there any difference in measuring the benefits and costs to public investments in a slack economy compared to a taut one? If there are underemployed resources in a region, then it is reasonable to expect that the change in economic rent will be less since it will be easier to entice resources from alternative employment with a minimal increase in factor price, i.e., supply will be more elastic. Also the project costs should be reduced since the price of the needed capital and labor inputs will have lower opportunity cost.[10]

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[10] Mishan states that "... the advantages of public investment in times of low employment are made manifest by reference to the cost aspect. For where there is substantial unemployment, the opportunity cost of labor, skilled and unskilled, and indeed of specific forms of capital equipment, is much lower than if such factors are already employed. Thus investment projects that would not be economically feasible under conditions of full employment may be economically feasible under conditions of low employment -- assuming, of course, that employment is expected to remain low, at least in the absence of these investments" [p. 293].

When measuring benefits in a slack economy, we must also address the issues of dealing consistently with the problems of (1) saved resources that become underemployed and (2) underemployed resources that are re-employed for a given public investment. On the general issue of including changes in slack as a measure of economic growth Solow states:

> "One of the contributions of the modern theory of growth has been to put a damper on loose discussion of policy directed to change the rate of growth. The year-to-year growth of real output in an economy has three elements. Some of it comes from year-to-year changes in the degree of utilization or slack in the economy, as measured by unemployment rate or rate of capacity utilization. An economy can grow faster or slower from one year to the next because its unemployment rates is falling or rising. If this is to be described as growth, it is specifically growth of demand, not growth of supply. Growth in supply, or productive capacity, has two further components. One is the underlying steady-state rate of growth, the natural rate, the other is the growth that comes form a current or recent change in the proportion of output invested. The theory says that this last component of growth is transitory" [7, p. 78].

Solow suggests that it is the responsibility of the government, through its fiscal and monetary policy, to maintain a "fairly steady" rate of employment. Solow also recommends that the criteria for public investment should be "to keep the marginal product of industrial capital equal to the marginal product of overhead capital at every instant of time" [7, p. 94]. This suggests that the federal government's responsibility to maintain full-employment by shifting aggregate demand is separate from its (or other governmental units) responsibility to make investments in infrastructure based on marginal productivity and measured as benefit/cost or internal rate of return. This implies that the re-employment of underemployed resources from infrastructure investment should not counted as an additional benefit of a government's supply-side investment policies beyond those outlined above.[11] Similarly, saved

[11] Mishan takes the opposite point of view regarding secondary effects. However, he implies that the strongest case for including secondary effects can be made only under a narrowly defined set of circumstances. "... cost-benefit calculations that take no account of ... secondary income and employment effects will underestimate the net benefits of the projects involved. Although allowance for these secondary income effects should obviously be made -- at least wherever, under existing political circumstances, no

resources that become underemployed as a result of infrastructure investment should not be subtracted as a cost.[12] In both cases, the change in underemployment is properly a measure of the performance of the federal government's fiscal-monetary policies. To include the effects of underemployed or immobile resources of a slack economy into benefit/cost analysis is tantamount to weighting a long-run investment measure by the effect of the

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alternative ways of expanding employment are anticipated -- we shall restrict ourselves ... to the primary employment effects" [p. 294].

[12] This result contradicts that reached by Schmitz and Seckler. "In order to determine the value of the harvester, we have to determine whether the gainers (producers, consumers, etc.) could compensate the losers (workers) and still be better off than before [p. 574]. And "... compensation is a necessary but not a sufficient condition for appraising an improvement [p. 575, fn 11]. Since economic surplus is equal to resources saved, the Schmitz and Seckler criterion reduces to a question of opportunity cost and asset mobility. Beyond this, it is assumed that separate economic measurements of efficiency and distribution can be made and therefore should not be lump together. The choice between equity and efficiency is ultimately a political one.

federal government's short-run fiscal and monetary policy on structural adjustments. Therefore, it is concluded that the procedure for measuring the direct and indirect benefits from investments in infrastructure as the change in economic surplus should be the same in the context of either a taut or slack economy.

SUMMARY AND CONCLUSIONS

The benefits in a benefit/cost analysis are measured by changes in economic surplus. An increase in total factor productivity will increase economic surplus. Increases in homogeneous capital do not increase productivity. However, value-added information, including the change in capital and labor intensity, can be used to determine the change in productivity that is a necessary component of economic surplus.

It is shown that the change in value added less the changes in capital and labor intensity equals total factor productivity. It is important to note that total value added over-estimates changes in productivity since it also includes changes in capital and labor intensity. Thus, by itself, value added is not the measure of benefits needed for a benefit/cost analysis. However, the growth in value added is a necessary component in determining the change in total factor productivity. Productivity is necessary information in estimating economic surplus as the measure of the benefits accruing from public investments. Diewert's quadratic lemma can be used to compute an ideal index of productivity from information on value added.

It is also concluded that economic surplus is the appropriate measure of benefits in either a taut and slack economy. Nonetheless, the temptation to use value added directly as a measure of benefits can be great. Especially for a poor community, the secondary effects from using unemployed and under-employed labor and capital seductively suggests using adjusted value added as a measure of benefits to public investment. If employment increases as capital investment increases, then real growth in value added will occur until a fixed rate of unemployment is reached. To some, this may seem to justify using an adjusted value added to measure the benefits to public investment in a depressed region, although a true measure of the benefits is an estimation of the change in economic surplus. These instances serve to point out the pressure an analyst can come under to incorrectly use value added as a direct measure of benefits from a public investment.

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