Distributional effects of agricultural productivity in benefit cost analysis: alternative weighting of benefits and costs

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Invited paper presented at the 5th International Conference of the African Association of Agricultural Economists, September 23-26, 2016, Addis Ababa, Ethiopia

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Distributional effects of agricultural productivity in benefit cost analysis: alternative weighting of benefits and costs

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Abstract: This paper proposes a methodology to weight benefit/cost analysis in a way that increases the policy focus on food insecure households. Such a weighting may be important to policy makers such as the Consulting Group for International Agricultural Research who must choose between research and development alternatives in developing countries. Specifically, the weights can be set to emphasize the needs of low-resource households and smallholder agriculture.

Keywords: welfare weights, food security, research and development choice.

JEL Numbers: O11, Q16, D61

I. Introduction

Cost/benefit analysis based on producer and consumer surplus has become a mainstay of project analysis including the analysis of investments in developing countries (Currie, Murphy and Schmitz, 1971). In this approach, the change in the area under the consumer’s demand function is used to measure the economic benefits from a program such as the investment in agricultural research and development to develop a new seed variety (Just, Hueth, and Schmitz, 2004). Similarly, the change in the area between the market supply curve and the output price is used to measure the benefits to producers. In both cases (e.g., consumer and producer surplus) the market curves obfuscate the distributional impact of policy changes. Specifically, the market demand curve is defined as the horizontal summation of all potential consumers of the good. In many cases, these individual demand curves can be grouped to provide insights into the distributional implications of policy interventions. For example, the overall market for an agricultural output could be separated into the demand from food secure and food insecure households. These households will likely have different elasticities of demand for the commodity of interest. In the case of a staple crop such as rice, it is likely that the demand from food secure households is more inelastic than the demand from food insecure households. Hence, agricultural research and development investments that increase the supply of rice will entail distributional differences across households. This paper contends that these distributional differences should be taken into account in making investments under programs such as the United States Agency for International Development’s Feed the Future initiative. In fact, we propose weighting the benefit/cost analysis to explicitly consider such factors as food security.

Traditionally economists have weighted the areas in benefit/cost analysis equally. However, Harberger (1978) examined the economic implications of unequal weights. Beginning with the imposition of tariffs, Harberger demonstrates that weighting the economic impact on consumers and producers differently yields the same result as the construction of an optimal tariff. This paper considers a slightly different problem. Specifically, we are interested in the scenario where an international concern such as Consulting Group for International Agricultural Research (CGIAR) is allocating funds across a variety of agricultural research and development programs to enhance the productivity of smallholder agriculture. Our contention is that the goals of this group would be better represented by weighting the gains and loses – putting a larger
weight on the impact of each alternative on food insecure households and smallholder agriculture.

II. Theoretical Model

Under standard assumptions, an outward shift in the supply curve due to technological advances increases the quantity produced and consumed, and reduces the market price in a competitive market as depicted in Figure 1. The benefits from a technological change are not uniformly distributed across consumers. In Figure 1, \( D_{FS} \) depicts the demand for food in food secure households and \( D_{FI} \) is the demand for food in food insecure households – we assume that this demand curve is significantly more elastic than the demand curve for the food secure households. In addition, we segment the supply function into supply from smallholders \( (S_s) \) and the supply from larger farms \( (S_L) \).

Following the standard benefit cost-formulation, we assume that some investment in agricultural research and development increases the supply of food. The returns for an investment that yielded the observed shift in food supply would be

\[
B/C = \frac{\sum_{j=1}^{n} pcdp' + \sum_{j=1}^{n} pabp' + \sum_{j=1}^{n} gfh - pehp'}{\sum_{j=1}^{n} C_j} \quad (1)
\]

where \( pcdp' \) is the change consumer surplus for consumers for food secure households, \( pabp' \) is the change in consumer surplus for consumer change in consumer surplus for consumers in food insecure households, and the denominator is the present value of costs incurred to produce the new technology. As depicted in Figure 1, \( pcdp' \sqsupseteq pabp' \) - the gain in food secure households is larger.

In this study we question whether the benefits in the numerator of Equation 1 adequately depict the goals of donors or international agencies. Specifically, the gain to food insecure households may be far more important to these decision makers than the losses to either large producers or lower gains to food secure households. As a starting point, we focus on the gains as measured by consumer surplus. Consider a formulation of the consumer benefit which is a function of two weighting parameters \( (\psi_1 \text{ and } \psi_2) \)

\[
B(\psi_1, \psi_2) = \psi_1 (pcdp') + \psi_2 (pabp'). \quad (2)
\]

Under typical assumptions, \( \psi_1 = \psi_2 = 1 \). However, from the standpoint of international development agencies, they should also consider a scenario where \( \psi_2 > \psi_1 \) (i.e., the development agency is more interested in the impact of the intervention on food insecure households).

In order to more completely describe the policy question – let us assume that there are two policy alternatives

\[
B_1 = \psi_1 CS_{11} + \psi_2 CS_{12} \quad (3)
\]

\[
B_2 = \psi_1 CS_{21} + \psi_2 CS_{22}
\]
where $CS_{11}$ and $CS_{21}$ are the changes in consumer surplus from two different investment alternatives for the food secure households (i.e., $pcdp'$) and $CS_{12}$ and $CS_{22}$ are the changes in consumer surplus for these two different investment alternatives for food insecure households (i.e., $pabp'$). From the development agency’s standpoint, they should consider the relative strengths of investment in the first alternative if $B_1 > B_2$ and $B_1 > 1 + \delta$ (e.g., $\delta$ is some safety margin). The question addressed here involves the scenario where the relative distribution of gains is markedly different between alternatives. For example what if the share of the gains going to food insecure households is much larger for the second investment

$$B_1 > B_2 \text{ but } \frac{CS_{12}}{B_1} < \frac{CS_{22}}{B_2} \quad (4)$$

(with $B_2 > 1 + \delta$ so the second alternative is still feasible)? To develop the weights which incorporate the considerations in Equation 4 – we first make one of these alternatives the index investment (for this example – we use the first investment as the index alternative). Using this assumption, we impose the restriction that the choice of weight does not change the benefit/cost ratio for the index investment

$$dB_1 = CS_{11}d\psi_1 + CS_{12}d\psi_2 = 0$$

$$\Rightarrow d\psi_2 = -\frac{CS_{11}}{CS_{12}}d\psi_1 \quad (5)$$

Table 1 gives the value of $C_{11}$ as 10.781 and $C_{12}$ as 3.612 for the first alternative, giving

$$d\psi_2 = -2.985 d\psi_1 \quad (6)$$

If the change in weight for food secure households is $d\psi_1 = -0.05$, the change in weight for food insecure households increase by $d\psi_2 = 0.149$, the consumer benefits for the first investment alternative remain unchanged.

### III. Empirical Model

In order to demonstrate the effect of increasing the weight on food insecure households, we formulate a stylized market with an original quantity of 100.0 and market clearing price of 5.00. The supply and demand curves in Figure 1 are then parameterized using a general logarithmic function which yields constant elasticities of supply and demand

$$f(p) = \exp(a_0 + a_1 p) \quad (7)$$

Using Equation 7 to derive the demand curve for food secure households, we choose the parameters which return a total demand of 75 with a price elasticity of demand of -0.08. Specifically, we solve for the parameters $a_0$ and $a_1$ such that

$$\exp(a_0 + a_1 p) = 75$$

$$\frac{\partial \exp(a_0 + a_1 p)}{\partial p} \frac{p}{\exp(a_0 + a_1 p)} = -0.08 \quad (8)$$
Using the same approach, we solve for the parameters such that the price demand elasticity for food insecure households is -0.15 and their level of demand is 25. Extending the formulation slightly, we solve for the two supply functions given that both producer groups have an elasticity of supply of 0.65 with 70 units being produced by large producers and 30 units by smallholders.

Table 1 presents the changes in consumer and producer surplus for an investment that shifts the supply curves for both sets of producers to the right by 10 percent. In general, food secure households benefit more from this shift than food insecure households. However, the relative increase in consumer surplus for food insecure households becomes progressively larger as their share of demand increases.

Table 2 presents the benefit/cost ratios for each investment alternative assuming (1) the conventional one to one welfare weighting, (2) a weight of 0.950 on food secure households and 1.149 on food insecure households, and (3) a weight of 0.920 on food secure households and 1.239 on food insecure households. Comparing the first line in Table 2 with the results in Table 1, we see that the change in consumer surplus remains unchanged (e.g., consistent with Equation 5). Turning to the second line of Table 2, the original benefit cost ratio for this scenario is identical to the first (i.e., the first row in Table 2) with the original one-to-one ratio. However, if we increase the weight on food insecure households by 0.149, the second alternative dominates the first – the benefit/cost ratio for alternative 1 remains 1.216 while the benefit/cost ratio increases to 1.226 for the alternative 2. Moving from an increase in the weight from 0.149 to 0.239 further increases the benefit/cost ratio from 1.226 to 1.232.

IV. Conclusions and Discussion
Given the development concerns of such organization as Consulting Group for International Agricultural Research, the traditional one-to-one weighting of the components of benefit/cost analysis may not meet the goals in choosing among investment alternatives. Hence, this study examines the possibility of weighting the benefits of areas of concerns differently. In this paper we consider increasing the weight on food insecure households relative to food insecure households. The stylized results demonstrate that this weighting increases the benefit/cost ratio for investments that benefit food insecure households.

Given the viability of weighting, the next question is: What should determine the relative weight on food insecure or other target groups? Several alternatives come to mind such as some measure of importance of relative expenditures on food. For example, the weights could be related to the marginal budget share spent on food. Alternatively, the weights could be linked to nutritional goals – the number of children who experience stunting or wasting or the relative number of people below some other nutritional standard such as calories per day.

References
Table 1. Annual Benefits and Cost of Investment in Agricultural Research and Development

<table>
<thead>
<tr>
<th>Consumer Shares</th>
<th>Producer Shares</th>
<th>Consumer Surplus</th>
<th>Producer Surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Secure</td>
<td>Food Insecure</td>
<td>Large Holder</td>
<td>Small Holder</td>
</tr>
<tr>
<td>1 0.75</td>
<td>0.25</td>
<td>0.70</td>
<td>0.30</td>
</tr>
<tr>
<td>2 0.65</td>
<td>0.35</td>
<td>0.70</td>
<td>0.30</td>
</tr>
<tr>
<td>3 0.55</td>
<td>0.45</td>
<td>0.70</td>
<td>0.30</td>
</tr>
<tr>
<td>4 0.75</td>
<td>0.25</td>
<td>0.60</td>
<td>0.40</td>
</tr>
<tr>
<td>5 0.75</td>
<td>0.25</td>
<td>0.50</td>
<td>0.50</td>
</tr>
</tbody>
</table>
Table 2. Weighted Benefit/Cost for Investment in Agricultural Research and Development

<table>
<thead>
<tr>
<th>Original Weight</th>
<th>Food Secure</th>
<th>Food Insecure</th>
<th>Consumer Surplus</th>
<th>Benefit/Cost</th>
<th>$d\psi_2 = 0.1492$</th>
<th>Food Secure</th>
<th>Food Insecure</th>
<th>Consumer Surplus</th>
<th>Benefit/Cost</th>
<th>$d\psi_2 = 0.2388$</th>
</tr>
</thead>
</table>
Figure 1. Distribution of Benefits from Technical Advances in Agriculture