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K. W. Easter, M. Abel, and G. Norton in Regional Differences in Agricultural Productivity in Selected Areas of India (March 1976) measured the contribution of various inputs to total output in the Eastern Rice Region (ERR) of India. This research uses their estimated production elasticity on surfaced roads in figuring a benefit-cost measure of public investment in surfaced roads in the ERR. First a model was set up to calculate the benefits and then the costs, and finally they were joined in a benefit-cost ratio. Although the calculations are not precise because of the lack of information, errors, if any, are made on the side tending to lower the ratio of benefits to costs. Despite this, the results indicate that increasing surfaced road density in the ERR has a high payoff.

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# BENEFIT-COST ANALYSIS OF SURFACED ROADS IN THE EASTERN RICE REGION OF INDIA

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John Spriggs

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# BENEFIT-COST ANALYSIS OF SURFACED ROADS IN THE EASTERN RICE REGION OF INDIA*

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John Spriggs**

K. W. Easter, M. Abel and G. Norton in a recent study [1976] attempted to measure the contribution of various inputs to total output in the Eastern Rice Region (ERR) of India.[1/] They included both the traditional inputs such as land, labor and fertilizer, as well as non-traditional inputs such as irrigation, technology, environmental factors and infrastructure. They estimated production functions using district level data and found that the production elasticity on surfaced roads was highly significant and very stable under alternative equation specifications. The present research note uses their estimated production elasticity on surfaced roads (0.208) in estimating a benefit-cost measure of public investment in surfaced roads in the ERR. In the paper we first set up a model to estimate the benefits, then costs are estimated and finally, the estimated benefits and costs are joined together in a benefit-cost ratio.

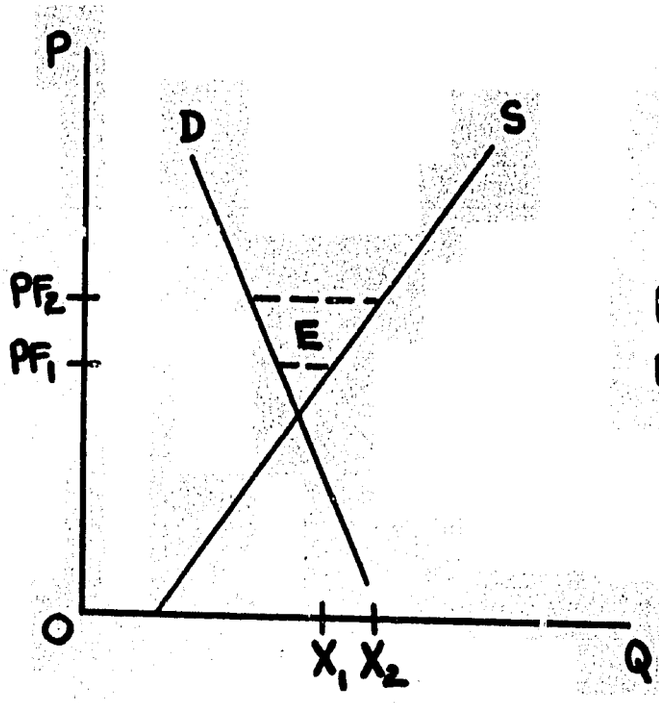
According to the Easter-Abel-Norton (EAN) study: "Surfaced roads appear to be important in explaining productivity differences among districts. . .The absence of roads has the effect of raising input prices paid by farmers and lowering output prices received by them due to higher transportation costs." Following this, the benefits of public investment

in surfaced roads may be assessed as follows. Consider figure 1 which depicts the basic economic interrelationships between the rural producing and consuming sector, the marketing sector and the non-rural consuming sector. Figure 1(a) describes the supply (S) and demand (D) curves for the rural or food surplus area. Figure 1(b) describes the excess supply (ES) curve from this area and a demand (DU) curve for the urban or food deficit area. Figure 1(c) describes the supply (SM) and demand (DM) curves for marketing services where it is assumed the supply of marketing services is perfectly elastic over the observed range of services suppl. This is thought to be reasonable, in the absence of congestion costs, following some earlier research [for example, Ruttan, 1969].[2/] Using a perfectly competitive model, the last-mentioned curve is a vertical subtraction of the ES from the DU curve. Equilibrium prices at the farm level ($PF_1$) and wholesale level ($PR_1$) and the equilibrium quantity flowing through the system ($OX_1$) are determined by the intersection of the DM and SM curves in figure 1(c). Total quantity supplied by the rural sector is $OX_1$.

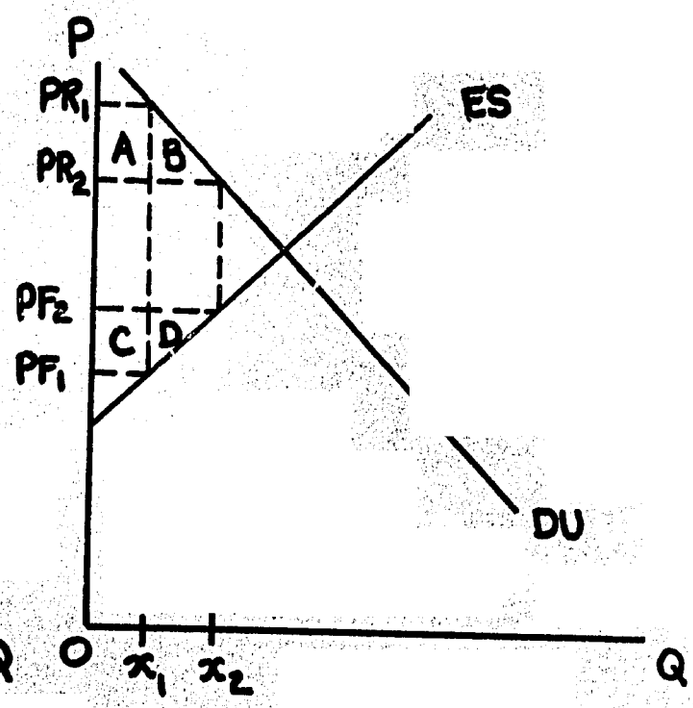
The effect of increasing surfaced roads is to lower both the prices of purchased inputs to the rural producer and the costs of transporting the product to the food deficit area. These effects manifest themselves in downward shifts in the S and SM curves respectively.

Ideally, we would like a direct measure of these shifts to determine a unique solution to the gain in economic surplus, but these are not known. However, we do have an estimate of the effect of increasing surfaced roads on crop output from the EAN study. Using this information, we can obtain solutions that encompass a broad range of possible solutions.

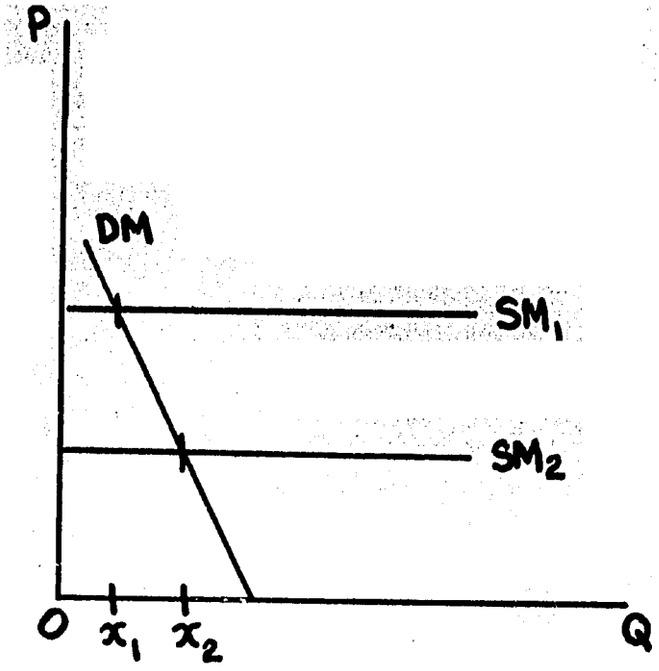
Figure 1. The Gain in Economic Surplus When it is Assumed Marketing Costs are Reduced but Input Prices are Constant




(a) Rural demand and supply of crop output




(b) Urban demand and supply




(c) Demand and supply of marketing services

In this note we shall obtain three such solutions, coinciding with the following possible situations.

(a) The SM curve shifts but the S curve does not. This assumes the investment in more surfaced roads decreases marketing costs but does not affect input prices. As a result, product price decreases in the urban sector and increases in the rural sector.

(b) The S curve shifts but the SM curve does not. This assumes that more roads decreases input prices but has no effect on marketing costs. As a result, product price in both the rural and urban sectors will decline.

(c) Both the S and SM curves shift so as to leave farm price unchanged. This assumes that more roads decreases both input prices and marketing costs. As a result, the farm price of output does not change but the urban price decreases.

As we shall see, these three situations yield respectively a high, low, and intermediate estimate of the benefits derived from building more surfaced roads in the ERR.

Let us consider in some detail the method of solving for the gain in economic surplus under assumption (a).

We postulate that a one percent increase in surfaced roads leads to an increase in rice output of (n × 100) percent. In figure 1 this is represented by the increase from $X_1$ to $X_2$. Thus, $n = \frac{(X_2-X_1)}{X_1}$. While the end result of more roads is greater output, we assume this occurs only because the increase in roads has reduced the cost of transferring product

from the farm to the non rural consumer. Therefore, the supply of marketing services curve shifts from $SM_1$ to $SM_2$. Price paid by the urban consumer falls from $PR_1$ to $PR_2$ while the price to producers rises from $PF_1$ to $PF_2$. The rural population has a net gain of area (E) in figure 1(a) which is equivalent to area (C + D) in figure 1(b). Urban consumers gain area (A + B) in figure 1(b).

Thus, annual net gain in economic surplus (a.n.g.) = area (A + B + C + D)

$$= 1/2(x_1 + x_2)[(PR_1-PR_2) + (PF_2-PF_1)].$$

Using the relation, $n = \frac{(X_2-X_1)}{X_1}$, and the approximate elasticity relations:

$$\text{elasticity of urban demand} = E(DU) \approx -\frac{(x_2-x_1)/x_1}{(PR_1-PR_2)/PR_1};$$

$$\text{elasticity of rural supply} = E(S) \approx \frac{(X_2-X_1)/X_1}{(PF_2-PF_1)/PF_1};$$

$$\text{elasticity of excess supply} = E(ES) \approx \frac{(x_2-x_1)/x_1}{(PF_2-PF_1)/PF_1};$$

we obtain, $(x_1+ x_2) = x_1 + x_1(1 + n \cdot \frac{E(ES)}{E(S)})$,

$$(PR_1-PR_2) = -\frac{PR_1 \cdot n \cdot E(ES)}{E(DU) \cdot E(S)}, \text{ and}$$

$$(PF_2-PF_1) = \frac{n \cdot PF_1}{E(S)}.$$

Thus, we obtain, $\text{a.n.g.} = \frac{x_1 \cdot n}{2E(S)} [(2 + n \cdot \frac{E(ES)}{E(S)}) (PF_1 - \frac{PR_1 \cdot E(ES)}{E(DU)}]$.

Thus, to determine a value for a.n.g. we shall assign values to $x_1$, n, E(S), E(DU), E(ES), $PR_1$ and $PF_1$, as follows.

(a) The initial quantity of rice marketed in the ERR($x_1$). This was determined as:

$$x_1 = \sum_{i=1}^{6} [(\text{rice output})_i \times (\text{percent marketed})_i]$$

where: i = 1,..., 6 are the states, Andhra Pradesh, Bihar, Madhya Pradesh, Orissa, Uttar Pradesh and West Bengal.[3/] "Rice output" data are for those states or parts of states included in the ERR. "Percent marketed" data are at the state level only. The values for rice output, percent marketed, and hence, $x_1$ were calculated for the marketing years 1967/68 and 1968/69 and a simple average over the two years was used: Thus, $x_1$ = 37,230,000 quintals (qtl) [sources: 3, 1972; 4, 1972; unpublished data].

(b) The percent increase in rice output resulting from a one percent increase in surfaced roads (n). For this we shall use the coefficient on surfaced roads obtained in the EAN study, table 6, regression 8. Its value is 0.208.[4/]

(c) The price elasticity of rice supply (E(S)). Its value is an estimate obtained in a study using Punjab data for the period 1914-1945 [Krishna, 1963]. E(S) = 0.59.[5/]

(d) The price elasticity of demand facing non-rural consumers (E(DU)). Its value is an estimate obtained from a recent study using all-India data for the period 1951-1968 [Pandey, 1973]. Thus, E(DU) = -0.75.

(e) The initial price facing non-rural consumers ($PR_1$). For each of the six states in the ERR, data were obtained on the annual average wholesale prices of rice at selected markets in 1968 and 1969. The number of markets varied between states from 3 to 6 depending on the availability of data. Those in which prices were fixed by the Government were omitted. For each state a simple average price was determined over the relevant markets and over the two years. The six simple average prices were weighted by the quantity of rice marketed in each state (or part of state) to obtain $PR_1$. Thus, $PR_1$ = Rs 113/qtl. [Source of price data: 4, 1972.]

(f) The initial price received by producers ($PF_1$). Let $PF_1 = PR_1 - M_1$, where $M_1$ = the marketing margin when $x_1$ is marketed. No data could be found on the size of $M_1$. Thus, it was arbitrarily decided to assume $M_1 = 0.1\ PR_1$, and use the resulting value of $PF_1$. As it turns out, the solution was not very sensitive to the value of $PF_1$. For example, when $PF_1$ was reduced by 10 percent, the gain in economic surplus declined to only about 5 percent.[6/]

(g) The price elasticity of excess supply (E(ES)). We use the expression:

$$E(ES) = E(S) \cdot \frac{X_1}{x_1} - E(D) \cdot \frac{X_1 - x_1}{x_1}$$

where the values for E(S) and $x_1$ have already been determined. The value of E(D), the elasticity of rural demand, is assumed

to be equal to $E(DU) \cdot \frac{PF_1}{PR_1}$ or 0.68 and $X_1$, the initial quantity of rice produced in the ERR is determined as follows. Rice output in the ERR was calculated for each of the marketing years 1967/68 and 1968/69, and a simple average over the two years was used. Thus, $X_1$ = 207,970,000 qtl [sources: 4, 1972; unpublished data]. The value of E(ES) = 6.4.

Using the values obtained in (a)-(g) above, annual net gain in economic surplus was found to be Rs 141 million of which about 91 percent was distributed in the urban consuming sector.

Before considering the costs let us turn briefly to the estimation of benefits under the two alternative assumptions. We shall not detail the methods of solution as they are of the same geometrical variety that we have used above. Under these asuumptions in which the S curve shifts, we shall assume the shifts to be in a parallel fashion. Under the second assumption, where only the S curve shifts, annual net gain in economic surplus was found to be Rs 91 million of which about 88 percent was distributed in the rural sector. Under the third assumption, where both the S and SM curves shift in such a way as to leave PF unchanged, the annual net gain in economic surplus was found to be Rs 108 million of which about 60 percent was distributed to the urban consuming sector.[7/]

With regard to the costs of a one percent increase in surfaced roads in the ERR, we shall consider two types: development cost and maintenance cost.

To obtain estimates of these costs, annual data (1959-1969) were obtained on an all-India basis for (a) length of extra-municipal surfaced roads maintained by Public Works Department and Local Bodies, and

(b) development and maintenance costs of state roads (deflated by the wholesale price index for India, all commodities).[8/] [Source: 5, 1969.

A value for development cost was obtained by summing the deflated annual development costs over the ten year period and dividing by the difference in road length between 1959 and 1969. The average development cost determined in this way is Rs 56,700/km (1969 prices).

A value for maintenance cost was obtained by dividing the deflated annual maintenance cost by road length each year, 1959-1969, and then averaging the results. The average maintenance cost determined in this way is Rs 1,970/km/year (1969 prices).

It may be argued that since these costs are drawn from all-India data they may not accurately reflect the cost of constructing or maintaining roads in the ERR because the higher than average rainfall in this region will result in road costs above the national average. Moreover, we have ignored bridge costs. Therefore, let us be generous and double the cost figures arrived at above and use these adjusted costs in the following analysis.

Since total length of surfaced roads existing in the ERR, 1969 was about 51,000 km; to increase road length by one percent (or 510 km) involves a development cost of Rs 57.8 million (1969) and an annual maintenance cost of Rs 2.0 million (1969). [Sources: 5, 1971; 6, 1971.]

To obtain a benefit-cost measure we need to add assumptions about the flow of costs and benefits. Let us assume the new roads are constructed within a year, that the full benefits and maintenance costs accrue for each of the following 10 years. After this time the roads are scrapped with a zero salvage value. With regard to the rate of discount, since the

major part of costs occur at the start while the benefits are spread out evenly over ten years, we will obtain a lower benefit-cost ratio, the higher the discount rate. Let us then choose a discount rate on the "high" side, say fifteen percent, so that we will err if at all on the side that tends to lower the ratio of benefits to costs.

Allowing a fifteen percent rate of discount, the resulting benefit-cost ratios under the three alternative assumptions are as follows:

(a) The SM curve shifts, but the S curve does not: B/C

(b) The S curve shifts, but the SM curve does not: B/C = 6.7.

(c) Both the S and SM curves shift in such a way as to leave PF unchanged: B/C = 8.0.[9/]

The results indicate that benefits relative to costs are very substantial, and hence, that a lack of surfaced roads in the Eastern Rice Region of India is likely an important constraint to development there.

The Easter, Abel and Norton study [1976] isolates the effect of surfaced roads as a regression coefficient. The present research note attempts to translate their result into a benefit-cost ratio. Although the calculations lack precision because of the sparsity of information, we have chosen to err, if at all, on the side that will tend to lower the ratio of benefits of costs. Despite this, the results indicate that increasing surfaced road density in the Eastern Rice Region has a high payoff.

## FOOTNOTES

*University of Minnesota Agricultural Experiment Station, Scientific Journal Series Paper No. __. I wish to thank Martin Abel, William Easter, Willis Peterson, Terry Roe, Peter Warr, and Ian Wills for their helpful comments. The author is responsible for any remaining errors.

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1/ The ERR as defined by Easter and Abel [1973] contains 69 districts in the states of Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh and West Bengal.

2/ One may still argue that the type of marketing services required as a result of more surfaced roads may differ from the type envisaged by Ruttan. For example, storage facilities may become more specialized and the method of transportation may be more capital intensive. These would tend to imply an upward sloping long run supply curve for marketing services.

3/ The district of Bhandara (Maharashtra) is included with Madhya Pradesh

4/ We should be aware that the dependent variable in the EAN study is total crop output of which rice is the major crop. In this research note "the dependent variable" is simply rice output. The implications are as follows. If in fact all crops increase in output by about the same percent, then we shall be underestimating the benefits by ignoring those benefits accruing to the non-rice crops. If in fact only rice increases in output while other crop outputs remain the same or decline, then we shall be underestimating the benefits because the roads coefficient in the EAN study will be lower than if "rice output" were the dependent variable. The converse holds if other crop outputs increase while rice output does not.

5/ While the elasticity may be suspect since it neither pertains to the same region nor similar time period considered here, the benefits are not overly sensitive to changes in this elasticity. A 10 percent increase in this elasticity leads to a reduction in the a.n.g. of 4 percent under the first assumption, an increase of 4 percent under the second

6/ Under the second and third assumptions, a 10 percent reduction in $PF_1$ will reduce the a.n.g. in economic surplus by 4 percent in each case.

7/ While we have assumed parallel shifts in the S curve under both the second and third assumptions, an alternative assumption of proportional shifts has a substantial effect on the a.n.g. in economic surplus. Recalculating the gains under this alternative assumption yields the values of Rs 51.6 million and Rs 86.6 million, respectively.

8/ State roads includes extra-municipal surfaced roads maintained by PWD and Local Bodies. However, unsurfaced roads are also included in state roads. Hence, to this extent, the costs obtained in this note will probably be biased upward.

9/ In the second and third cases, if we assume that the S curve shifts in a proportional rather than a parallel way, the B/C ratios are then 3.8 and 6.4, respectively.

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