Ex Ante Analysis of the Impact of New Technology: The Case of Cassava as an Animal Feed in Colombia

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Numerous studies have shown that technological innovation is a key factor in promoting economic growth and that the returns to investment in research on agricultural technology are very high indeed (Arndt et al; Akino and Hayami). Given the widespread recognition of the importance of research to growth in agricultural productivity, increasingly economists are devoting attention to raising the productivity of current research expenditures.

Better definition of research priorities is one area where economists have attempted to contribute to the productivity of research by suggesting to breeders and other scientists the particular characteristics of technology that will have the greatest economic returns. Previous research has consisted primarily of ex post estimation of the benefits of new technology. Some recent studies, however, have undertaken and ex ante analysis that delineates features that should be included in new technology.

Ladd and Gibson for, example, estimated the relative profitability to U.S. hog producers of breeding for backfat, feed efficiency or average daily gain. Bollard assessed the farmer preference for three broad crop characteristics- profitability, growth rate, and variability- in order to help define more specific breeding priorities.

This paper estimates the economic gains from developing cassava as an animal feed in Colombia. While previous ex ante studies have focused on the benefits and preferences of individual producers, here the total economic gains to society will be considered by utilizing the concept of economic surplus which has been the main methodology of the ex post studies, but is here adapted to ex analysis.

Although cassava is primarily consumed fresh for direct human consumption in Colombia, it also has the potential to be used as an animal feed. Feed concentrates production has been rapidly growing mainly due to the expanding production of poultry. The income elasticity of demand for poultry in Colombia is higher than for any other foods (FAO 1971) and the rate of growth in consumption of poultry has exceeded that of nearly all other foods.

Accompanying this boom in poultry has been a striking increase in the production of sorghum for animal feed, not only in Colombia, but also in much of Latin America. Despite the brisk growth in sorghum output, many countries, among them Colombia, Mexico, and Venezuela, have found that even sorghum growth rates in excess of 10% annually in the 1970's have left them needing to import substantial quantities of feed grains. Based on these trends, it is projected that feed grain imports in Latin America will increase by 1985 to between 40% and 100% above 1974-76 levels (FAO 1979).

Cassava can clearly be used in large quantities as an animal feed given the example of high use of Thai cassava pellets in the EEC feed concentrates industry. Moreover, while sorghum is typically a large farm crop in Latin America, cassava is produced primarily by small farmers with relatively labor intensive technology. Cassava also has the advantage over sorghum that it can be produced on acid soils under more severe moisture stress. Hence, the widespread production of cassava as an animal feed could help displace large feed grain imports; provide small farmers with an increased market for their crop; stimulate rural employment; and exploit the underutilized soils of the acid savannahs.

While the use of cassava as an animal feed in Colombia has numerous potential benefits, from the points of view of policy makers allocating scarce resources among alternative research programs and of scientists defining the specific objectives desired in improved germ plasm, it is important to know whether the economic returns from cassava as an animal feed are likely to justify breeding towards varieties that would be suitable for this market even it they could not enter the fresh market for human consumption.

The characteristics required of cassava destined for the animal feed market are significantly different from those required in the fresh market. Fresh cassava must be low in toxic hydrocyanic acid (HCN); resistant to post harvest deterioration; high in starch content; quick cooking and tastey. This is a set of very strigent, and perhaps somewhat contradictory quality standards since post harvest deterioration and starch content seem to be inversely correlated. Cassava that does not meet minimum standards on these characteristics will not be widely acceptable on the fresh market.

Quality standards for cassava in the animal feed market, however, are much less demanding. HCN is not such a concern because it is almost entirely broken down when cassava is dried before milling. Cooking and taste are clearly not relevant in this market. High starch content is desirable, but largely insofar as it leads to a higher yield of starch per hectare. Cassava with a starch content as low as 22% has been used sucessfully as an animal feed in Thailand while starch content in cassava for fresh consumption in Colombia must be about 30% to satisfy consumer preferences. Finally, resistance to rapid post harvest deterioration is certainly and advantage even in the animal feed market, but once cassava is dried it can be stored for long periods.

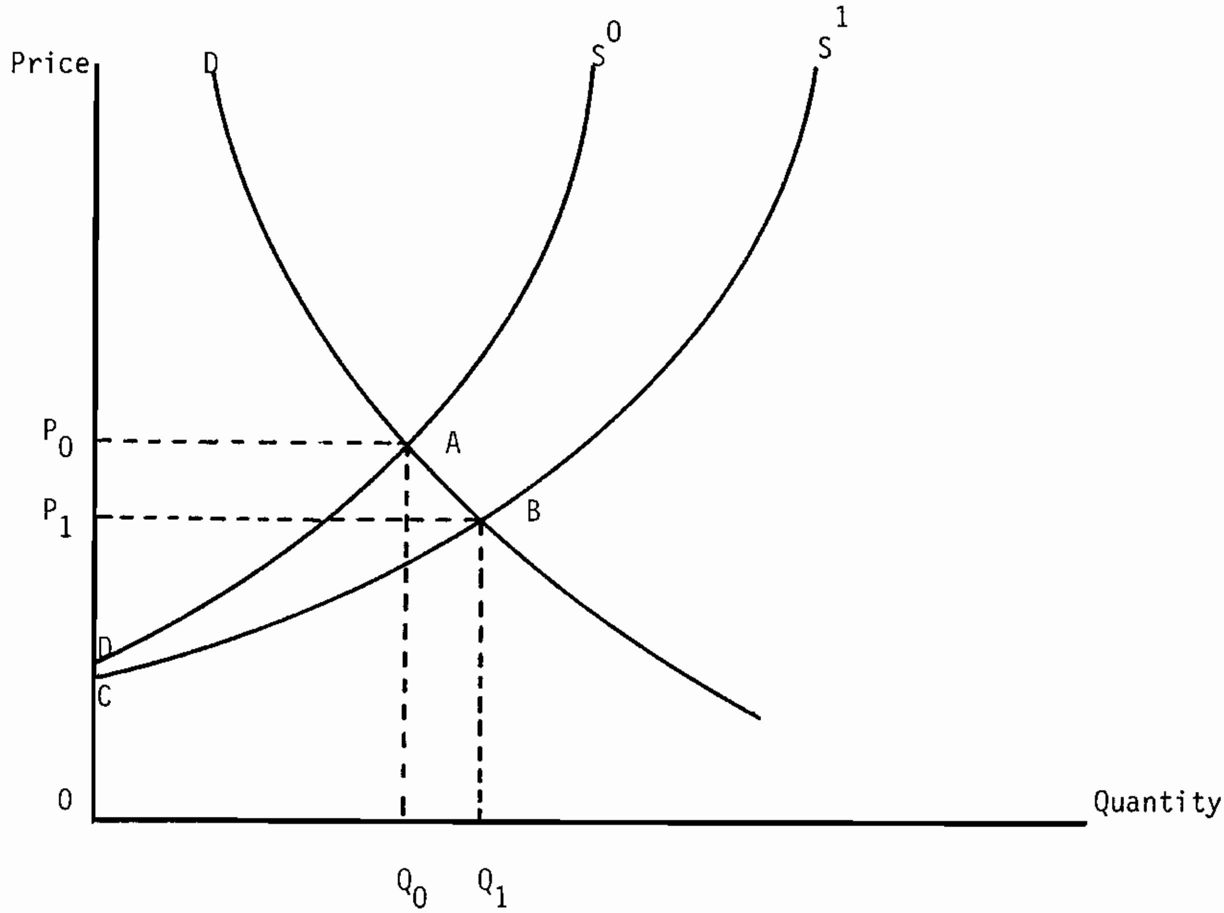
Since the difficulty of developing new genetic material increases with the number of breeding objectives, both the cost and the time necessary to produce a suitable high yielding cassava variety for use as an animal feed is likely to be less than that required to develop a variety acceptable on the fresh market. Thus, a breeding strategy that first concentrated on developing high yielding cassava for the animal feed market, then later added on some of the additional characteristics essential for the fresh market, might be attractive if there were sufficient economic gains accruing from the animal feed market.

This paper therefore, first reviews the methodology for evaluation the economic benefits of new technology and presents a model for use in the ex ante analysis of new cassava production technology. Second, the supply shift induced by new cassava technology is simulated by using a linear programing least cost feed mix model and a Nerlovian supply equation. Third, elasticities of supply and demand for poultry in Colombia are estimated for use in the benefits model. Finally, the economic benefits are computed and the implications for cassava research strategy are discussed.

The Model

The methodology for measuring the economic returns to research is well developed and has frequently been utilized to estimate the gains from past technological innovations (see Akino and Hayami; Ayer and Schuh;Evenson and Flores). The economic returns from research are concieved as consisting of the area of economic surplus resulting from a rightward shift in the supply function induced by a change in production technology, area ABCD in Figure 1

Figure 1 The Benefits of New Technology



This area is equal to

$$(1) \quad K P_1 Q_1 + \frac{P_1 Q_1 (K(1+e))^2}{2(e+n)}$$

where P_1 and Q_1 are the equilibrium price and quantity after the technological change; k is the increase in production attributable to research expressed as a percentage of Q_1; and e and n are the absolute values of price elasticities of demand and supply (the formula is from Akino and Hayami).

Previous studies of the economic benefits of research have analyzed technological changes that had already occurred so that P_1 and Q_1 were directly observable. It was necessary to estimate demand and supply functions to obtain the needed price elasticities and also some estimate was needed of the percentage increase in output associated with the new technology. Since this study deals with the potential gains from a technology, P_1 and Q_1 are not observable and must be estimated in addition to the price elasticities. Moreover, the approach to the estimation of the incremental output due to the new technology will be somewhat different.

The equilibrium price and quantity that will prevail after an exogenous shift in the supply function can be estimated from two equations (Pinstrup-Andersen et al 1976).

$$(2) \quad P_1 = P_0 \quad (1-(B/(n+e)))$$

$$(3) \quad Q_1 = Q_0 \quad (1+B/(1+(n/e)))$$

where P_0 and Q_0 respectively are the equilibrium price and quantity before the supply shift; B is the increase in production as a percentage of Q_0; and all other variables are as defined above.

The shift in supply due to improved production technology has typically been estimated either by fitting a production function including a variable that represents the technological change to data that covers a time period with and without the technology; or it has been estimated by computing some index or average of the productivity difference between the new and former technologies (Scobie). In this paper the effect of a new production technology for cassava on the supply of poultry will be simulated using a linear programing least cost feed mix model. The impact of new cassava production would be to lower the cost of production, hence the price, of cassava. The cost reduction in poultry feeds from cheaper cassava can be computed from the linear programing model while the effect of less expensive concentrates on the supply of poultry can be derived from a poultry supply equation.

Empirical Results: Estimation of Supply Shift

The first step to calculating the supply shift in poultry due to the availability of cassava as a low cost animal feed is to estimate the fall in the price of cassava that would result from an improved cassava production technology. To achieve this, it is essential to consider the likely nature of high yielding cassava production technology.

Since other crops are typically more profitable than cassava in high fertility or irrigated conditions, most cassava today is grown on soils of moderate to low fertility in rainfed areas. Consequently research on new cassava technology focuses on acheiving higher yields with minimum inputs (Cock and Lynam). Physiological studies indicate that substantial yield increases should be obtainable by breeding for plants with the optimum distribution of photosynthetic energy between leaves and roots (CIAT). Varieties can also be selected for their resistance to limiting deseases and pests (Lozano et al). Thus, it is expected that yield improvements can be acheived mainly through improved varieties complemented by a few low cost changes in agronomic practices such as better selection of planting material and the treatment of planting material with fungicide. It may be reasonable to set 15 tons per hectare as a tentative estimate of attainable yields under moderately stressful conditions with this technology package. Higher yields, perhaps up to 24 tons per hectare, may be possible by supplementing this package with chemical fertilizers and more effective weed control.

The price prevailing in competitive markets with new cassava production technology can be computed by costing all inputs at their opportunity cost since, by Euler's Theorem, in competitive markets equilibrium price is equal to the sum of the factor costs. Yields of 12,15 and 24 tons per hectare will be used to represent three potential levels of new technology. These are productivity increases of 33%, 67% and 167% respectively over the prevailing national average yield of roughly 9 tons in Colombia.

Current costs of production in Colombia are taken as the basis for costs under new technology from Diaz and Pinstrup-Andersen . The 12 and 15 ton yields are assumed to be attainable through improved varieties, stake selection and treatment of planting material while the 24 ton technology also includes the costs of additional weed control and the application of chemical fertilizer. A proportionate rise in harvest and packing costs is also added into the cost of all three technologies.

The prices of cassava generated by this process are then incorporated into a least cost feed mix model for poultry using Colombian prices for available inputs to concentrates. This feed mix model gives results very similar to the actual composition of concentrates produced in Colombia when current prices are used (see Pachico for fuller description of the model).

Table I Per Cent Reduction in Cost of Poultry Concentrates. With three levels of new cassava technology and three levels of inclusion of cassava in the feed mix.

Per Cent Cassava in Feed Mix	TECHNOLOGY 12 tons./ha.	15 tons./ha.	24 tons./ha.
10	0.4	1.3	1.9
20	0.7	2.6	3.8
43[a]	1.06	5.5	8.2

[a] Economic optimum at all levels of technology.

Table I shows the percentage reduction in the price of feed concentrates under various new technologies for cassava. For each technology cassava is entered at 10% and 20% of the feed mix as well as at the economic optimum as computed by the linear programing model, which is 43% of the ration at all technology levels.

The cost reductions from including cassava in the ration at less than the economic optimum are presented for two reasons. First, although cassava is commonly incorporated into poultry diets in Europe at levels as high as 5-20%, little is asyet known about the performance of poultry with greater quantities of cassava in the diet or about what ammendments to the diet would be needed in order to utilize cassava at such a level. Second, with the new technology for cassava production, cassava could completely displace sorghum from feed concentrates if sorghum prices were constant. However, it is likely that concentrate producers would at least initially prefer not to rely completely on a new source of feeds. Moreover, as cassava entered into serious competition with sorghum, high cost sorghum producers would tend to be driven out of business and the cost of sorghum would consequently tend to fall below current levels.

Supply and Demand Equations for Poultry

The impact of new cassava production technology on the supply of poultry can be calculated with the cost reductions presented in Table I when they are coupled with the elasticity of supply of poultry with respect to the price of concentrates. This latter figure can be derived from a supply equation for poultry. A straightforward Nerlovian model is estimated using annual Colombian data from 1960-78.

(4) $S_t = f (S_{t-1}, PP_{t-1}, PC_{t-1}, T)$

where S_t is the per capita supply of poultry meat: S_{t-1} is the supply of poultry lagged one year: PP is the consumer price of poultry in constant pesos; and T is a time trend variable.

Table II presents the results of the supply equation estimated in double log form by OLS. The signs of all variables are as expected; the fit is good; and there is no evidence of autocorrelation. From this equation the long run elasticity of supply of poultry with respect to the price of concentrates is 0.48. Taking, for example, the 2.6% cost reduction ensuing from a 15 ton per hectare cassava technology and 20% share for cassava in the feed mix, a supply shift of 1.25% would result due to the impact of higher yielding cassava on the price of feed concentrates.

To complete the computation of the new equilibrium price and quantity of poultry after a supply shift as per equations (1) and (2), estimates of the supply and demand elasticities of poultry are also needed. The long run supply elasticity of poultry can be obtained from the supply equation of Table II. The estimated value of 1.51 is reasonable, being well within the range of other reported supply elasticities for poultry (see Askari and Commings).

A poultry demand equation is also reported in Table II. Here the price of poultry is a function of the quantity of poultry per capita and the price of beef. The equation, estimated by OLS in double log form, is well behaved and yields a price elasticity of demand for poultry of 3.76. Although this is rather high, it is not inconsistent with the historic tripling of per capita poultry consumption in Colombia as the real price of poultry declined

Table II Supply and Demand Equations for Colombian Poultry, 1960-78. All variables in logs; 't' values in parenthesis.

Dependent Variable	Supply Poultry, t	Price Poultry, t
Intercept	-.363	1.362
Price Poultry, t-1	.428 (.91)	
Price Concentrates, t-1	-.135 (.98)	
Supply Poultry, t-1	.717 (4.12)	
Time	.808 (1.89)	
Supply Poultry, t		-.266 (5.06)
Price Beef, t		.129 (.64)
R^2	.98	.79
Durban Watson	2.27	1.76

over the period 1955-78 (see Janssen and Pachico for a more complete dis-scussion).

Economic Benefits of New Cassava Technology

From the demand and supply equations and the reductions in the cost of concentrates presented above, it is possible to compute the economic benefits of new cassava production through its impact on the animal feed and poultry market by using equations (1), (2) and (3). The gross benefits thus derived are presented for different levels of new cassava technology and different shares of the ration in Table III.

While these benefits can not be directly compared with costs because of the impossibility of estimating a priori the resources required to develop the alternative technologies, a rough comparison may be usefully made with the annual expenditures on cassava research made by the international center, CIAT, located in Colombia. Research expenses of $939,000 in 1978 exceed the annual expected returns from the 12 ton technology. Of course, it is not completely appropriate to compare the expenditures of an international center with the potential benefits that would accrue from only one country, nor is it accurate to attribute all the 1978 expenses to the development of cassava varieties for the animal feed market. Moreover, these results exclude any benefits that would be obtained from other sectors of the animal feed market-pork and dairy which account for about one fourth of feed concentrates consumption in Colombia.

Nevertheless, even though the difficulties of estimating the investment required to develop the various new cassava technologies prevent categorical conclusions as to the economic viability of research on cassava as a chicken

Table III Gross Benefits from Cassava as an Chicken Feed, Colombia. $ U.S. (000).

Per Cent Cassava in Feed Mix	TECHNOLOGY 12 tons./ha.	15 tons./ha	24 tons./ha.
10	208	658	973
20	353	1,320	1,941
43[a]	808	2,795	4,151

[a]Economic optimum at all levels of technology.

feed in Colombia, some general implications can be cautiously drawn. The economic returns to cassava as an chicken feed in Colombia appear to be fairly modest with the 12 ton per hectare technology at all levels of inclusion in the diet. On the other hand, reasonably substantial benefits occur with the 15 and 24 ton technologies.

The level of inclusion of cassava in the diet is an important determinent of gross benefits. For example, the gains would be greater from increasing the share of cassava in the diet from 20% to 43% with the 15 ton technology than they would be from increasing yields from 15 to 24 tons while remaining at the 20% inclusion level. This suggests a high priority to research on the acceptability of high levels of cassava in poultry rations.

Furthermore, the benefits from the 15 ton technology are about two thirds of those from the 24 ton technology even though the yield increase required to attain 15 tons per hectare is only 40% of that involved in reaching the 24 ton yield level. This is because the 24 ton technology is associated with the use of chemical fertilizers as well as more costly weed control measures. This pattern of benefits tends to support the research strategy of the CIAT cassava program which emphasizes low input technology.

Besides the net social efficiency benefits that improved cassava production technology would produce, it would also have a favorable impact on imports, balance of payments, employment, and incomes of cassava cultivators. At the 1979 level of concentrates production, inclusion of cassava at 20% of the poultry ration would lead to a demand for about 540,000 tons of fresh cassava. This may be compared with a total Colombian urban consumption of fresh cassava that does not exceed 150,000 tons of cassava. Hence, the animal feed market would vastly increase the opportunities of cassava producers to to expand sales and production.

Moreover, as was noted above, domestic feed grain production in Colombia does not suffice to meet demand, and sorghum was imported at an average level of 116,000 tons annually in the period 1976-79. About 315,000 tons of fresh cassava would go to replace these imports for foreign exchange savings of $12.7 million at 1979 world sorghum prices, exclusive of the cost of shipping.

Finally, there would be a substantial employment effect. At the 20% inclusion level with a 15 ton per hectare technology, some 4.2 million man days of employment would be created, roughly equivalent to full time employment for 15,600 in cassava production alone. Further employment would be created in the shipping, drying, and milling of cassava.

Summary and Conclusions

This paper has measured the economic benefits to be derived in Colombia from improved production technology for cassava of varieties suitable for use as poultry feed. The development of such cassava varieties imposes upon plant scientists far less exigous quality characteristics than would be required for cassava fit for the fresh vegetable market.

Such a new cassava production technology would lead to a shift in the supply curve of poultry due to a reduced cost of feed. The amount of cost reduction in feed concentrates associated with new cassava technology is simulated by a linear programing least cost feed mix model. The ensuing shift is computed by multiplying the decline in the cost of concentrates with the elasticity of supply of poultry with respect to feed concentrate prices. Own price elasticities of demand and supply are obtained from estimated demand and supply equations. With the supply shifts and the elasticities, it is possible to calculate the gross benefits due to different types of cassava production technology.

The model shows reasonably high gains either from minimum input technology with yields of 15 tons per hectare or from high input technology with yields of 24 tons per hectare. Although the costs of generating such new technologies can not accurately be estimated, the annual returns would clearly exceed total current yearly expenditures on cassava research incurred at the main international center for cassava research, CIAT.

Since the benefits from new cassava technology would be greatly increased if cassava could be fed successfully to poultry at rates higher than have prevailed historically at the farm level, further research on poultry performance with cassava constituting up to 45% of the diet seems warranted. Moreover, the present research strategy of emphasizing the development of mininum input technology for cassava is supported by the finding of relatively modest additional gains from high input 24 ton technology as compared with low input 15 ton per hectare technology.

This paper illustrates that *ex ante* analysis of the economic benefits from alternative new technologies can provide useful information in the planning of research priorities and strategies. Such analysis is seen, however, to remain partial, not only due to the inherent difficulties of estimating costs of research, but also because objective functions are multidimensional. For example, new cassava production technology would also save foreign exchange by displacing imported sorghum; create additional rural employment; provide vastly expanded markets for cassava producers; and subject domestic sorghum producers to stiff competition.

Although it may not be the function of economic analysis to weigh these various tradeoffs, it does seem that an important contribution can be made to the research planning process by providing decision makers with quantitive estimates of the impact of new technologies on all these relevant variables.

REFERENCES

Akino, Masakatsu and Yujiro Hayami. " Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development. " Amer. J. Agr. Econ. 57 (1975); 1-10.

Arndt, Thomas, Dana Dalrymple and Vernon Ruttan. Resource Allocation and Productivity in National and Intenational Agricultural Research. Minneapolis: University of Minnesota, 1977.

Askari, Hossein and John Cummings. Agricultural Supply Response. New York: Preager, 1976.

Ayer, Harry and G. Edward Schuh. " Social Rates of Return and Other Aspects of Agricultural Research: The Case of Cotton Research in Sao Paulo, Brazil. " Amer. J. Agr. Econ. 54 (1972); 557-569.

Bollard, Alan. " Grower Preferences for Crops and Implications for Plant Breeders. " Amer. J. Agr. Econ. 62 (1980) 530-533.

Cock, James and John Lynam. Cassava: Future Potential and Development Needs. Cali, Colombia: unpublished paper, CIAT 1979.

CIAT. Annual Report. Cali, Colombia, 1977.

Diaz Rafael. Per Pinstrup-Andersen and Ruben Estrada. Costs and use of Inputs in Cassava Production in Colombia: A Brief Description. Cali Colombia: CIAT 1974.

Evenson, Robert and P. Flores. " Social Returns to Rice Research " Economic Consequences of the New Rice Technology, Los Banos Philippenes IRRI 1980.

FAO. Proyecciones para Productos Agrícolas 1970-80. Rome 1971

FAO. Agricultural Commodity Projections. Rome 1979

Janssen, Willem and Douglas Pachico The Demand for Pork and Chicken in 1955-78: Implications for Cassava as an Animal Feed. Cali Colombia: unpublished paper, CIAT, 1980.

Ladd, George and Craig Gibson. "Microeconomics of Technical Change: What's a Better Animal Worth?" Amer. J. Agr. Econ. 60 (1978) 236-40.

Lozano, Carlos, David Byrne and Antony Bellotti. " Cassava/Ecosystem Relationships and their Influence on Breeding Strategy". Tropical Pest Management. 26 (1980) 180-187.

Pachico, Douglas. The Potential for Cassava in Least Cost Feed Concentrates in Colombia. Cali, Colombia: unpublished paper, CIAT, 1980.

Pinstrup-Andersen, Per, Norha de Londoño and Edward Hoover. " The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy ". Amer J. Agr. Agr. Econ. 58 (1976) 132-142.

Scobie, Grant. " Comments on Social Returns to Rice Research ". Economic Consequences of the New Rice Technology. Los Baños, Philippenes: IRRI, 1978.