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Impact of Research on Tea Production in Sri Lanka

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ABSTRACT. *This paper evaluates the impact of research investment by the Tea Research Institute of Sri Lanka on tea production. A national supply function for tea was estimated using time series data to achieve the primary purpose of the study. Lagged research expenditure was included as an explanatory variable in the model. Results of the estimation revealed that it has taken 19 years to observe any positive changes on the tea production, after the research investment is being made. There was 0.055 percent increase in current tea supply due to a one percent increase in research expenditure incurred 19 years ago. Research shows a geometrically declining lag effect suggesting that the favourable effects gradually fade away after 19 years.*

INTRODUCTION

Sri Lanka is the biggest exporter of tea in the world, earning 13 percent of foreign exchange through its tea exports. However, profit margin of the Sri Lankan tea producers is not very attractive due to high cost of production and low prices (Central Bank of Sri Lanka, 1996). Sri Lanka has the highest cost of production among major tea producing countries, such as India, Kenya, and Indonesia (Sivapalan, 1988).

A larger percentage of cost is attributed to labour and fertilizer, prices of which are determined exogenously. As a result, attempts to reduce cost of production depend heavily on the development and dissemination of new technology. New technology can affect the production in two ways. One way is to obtain a higher level of output using the same level of inputs (as in the case of high yield or disease resistant crop varieties). The other way is to obtain the same level of output using less amount of input (as in the case of an improved, labour - saving plough). Applied research is a means to generate new

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technology and is a tool widely used by many public and private institutes to reduce cost of production.

Tea research in Sri Lanka is undertaken by the Tea Research Institute. Research activities conducted by this Institute can be categorized into 3 main groups according to duration of the experiment and the time taken to disseminate the information to farmers. They are short term, medium term and long term research. Short term research include fertilizer trials, research on soil structure and nutrients and plucking trials. Medium term research include research on pruning, shade trees, processing technologies, and pests and diseases. Long term research mainly include development of new planting material. Many experts in the tea industry believe that invention of new planting material, *i.e.*, high yielding varieties, is the major factor that contribute to increase the productivity of tea. However, so far, no study has been conducted to evaluate the impact of such investments on tea production.

The objective of this study is to measure the impact of research on tea production. This objective is achieved by estimating a national tea supply function for the period of 1978–1994 with aggregate tea research expenditure as an explanatory variable.

MATERIALS AND METHODS

Theoretical framework

Minasian (1969) provides a theoretical model that includes research as an explanatory variable in the production function. The model begins with a production function that explicitly includes technology with the conventional inputs. A firm's technology (T) is a positive function of the existing stock of knowledge (N), and this knowledge is positively related to expenditure in research (RES), so that:

$$Q_t = f(L_t, K_t, T_t) \tag{1}$$

$$T_t = g(N_t) \tag{2}$$

$$N_t = h(RES_{t-k}, \dots\dots\dots, RES_{t-k-r}) \tag{3}$$

where at time t, Q_t is production, L_t is labour, K_t is capital and T_t is technology. N_t is the stock of knowledge and RES_{t-k} and RES_{t-k-r} research expenditure at time t-k and t-k-r, respectively. Parameter k shows the time after which benefits occur and parameter r shows the duration that benefits stay. The lag k is due to lags involved in: a) research expenditure and research findings, b) flow of new knowledge and the stock of new knowledge, and c) the new stock of knowledge and that actually in use. It should be noted that the implicit assumption underlying equation (2) is perfect knowledge transmission. In absence of an effective extension service such an assumption may not be realistic and extension expenditure should also be an argument in the knowledge function.

Substituting (1) and (2) into (3) gives production as a function of the factors and accumulated research expenditure.

$$Q_t = f(L_t, K_t, RES_{t-k}, \ldots\ldots, RES_{t-k-r}) \tag{4}$$

Assuming perfect competition[1], the output supply function, factor demand functions and profit function dual to above production function are given by equations (5), (6) and (7) and (8), respectively.

$$Q_t = f(P_t, WL_t, WK_t, RES_{t-k}, \ldots, RES_{t-k-r}) \tag{5}$$

$$L_t = f(P_t, WL_t, WK_t, RES_{t-k}, \ldots, RES_{t-k-r}) \tag{6}$$

$$K_t = f(P_t, WL_t, WK_t, RES_{t-k}, \ldots, RES_{t-k-r}) \tag{7}$$

$$\pi_t = f(P_t, WL_t, WK_t, RES_{t-k}, \ldots, RES_{t-k-r}) \tag{8}$$

1 Even if tea buyers have monopsony power, the structure of the functions (5)–(8) will not change. However, if tea producers have monopsony power in the fertilizer and labor market, the structure of the functions (5)–(8) will change in such away that value marginal product of the inputs would replace the market prices of input. In Sri Lankan tea sector, assumption of a perfectly competitive factor markets for tea producers is realistic.

where π_t, P_t, Wl_t and Wk_t are profit, prices of output, labour, and capital at time t, respectively.

One or more of these functions can be used to assess the impact of research. Selection of the type of function depends on the purpose of the study. Since the objective of this study is to measure the impact of research on tea production, production or output supply functions are good candidates for the analysis. This study uses a supply function due to possible multicolinearity problems with production function estimation.

Empirical specification of tea supply function

The previous section demonstrates that the impact of research on production can be described using a supply function, to achieve the primary purpose of this study. Supply function can be estimated either as a single equation or an equation in a system which consists of profit, input demand and output supply functions. Single equation estimation is convenient, when production involves dynamics. However, theoretical restrictions cannot be imposed with single equations.

Supply could be obtained by multiplying area planted with per acre yield. Research directly affects per acre yield. Therefore, in this study tea supply was specified as follows treating area planted as exogenous to the model:

$$\frac{Q_t}{A_t} = f(P_t, WL_t, WK_t, RF_t, RES_{t-k}, \ldots, RES_{t-k-r}, time_t) \tag{9}$$

where A_t = Area under tea at time t, Rf_t = index for rainfall at time t, and time = trend variable.

It should be noted that the above form of supply function ignores the effect of farm size on the production. It considers the number of labourers and amount of fertilizer as the conventional inputs used in tea production whose effects are captured by wage rate and fertilizer price in the supply function. To empirically estimate the supply function with research, decisions must be made regarding, a) type of research expenditure used, b) type of lag distribution on research imposed, c) type of output price lag imposed, and d) type of functional form used. Table 1 summarizes the different approaches used in previous studies.

Table 1. Functional Forms, Lagged Distributions, and Elasticities obtained from selected studies on research.

Study	Commodity	Functional form	Distribution	Elasticity
Huffman and Evenson (1989)	Feedgrain, Soybean, Wheat	Linear	Trapezoidal lags	n.a.
Haque, Fox and Brinkman (1989)	Laying hen	Linear Partial logarithmic	Polynomial	0.256 0.244
Fox, Roberts and Brinkman (1992)	Dairy	Log Log	Polynomial	0.258- 0.570
Chyc and Goddard (1994)	Egg	Log Log linear	one lag	0.14 0.15
Araji *et al.* (1995)	Potatoes	Linear	Polynomial	State:0.006 Regional:0.007
Sellen (1996)	Coffee	Linear log	Geometrical	Shortrun:0.37 Longrun:0.44
Zachariah, Fox and Brinkman (1989)	Broiler eggs	Linear	Polynomial	0.2653

The first task is definition of the research variable, which mainly depends on the context. Researchers should be able to make their subjective evaluation on the specific research expenditure series affecting production. Such expenditures could be lagged research expenditure on the specified crop in the location under consideration, and/or those of the neighbouring locations, those of similar crops *etc*. Some of the previous authors have allowed research to have a spill over effect from neighbouring states or countries. Araji *et al.* (1995) used two research expenditure variables, *i.e.*, research within the state and research within the subregion but outside the state, in an attempt to identify spill overs of research results. Fox *et al.* (1992), Zachariah *et al.* (1989), Haque *et al.* (1989) used lagged expenditure on both Canadian research and U.S. research to evaluate the impact on Canadian production. Huffman and Evenson (1989) used crop research expenditure and agricultural extension expenditure and evaluated the bias effects toward and against different crops and different inputs. Sellen (1996) used lagged coffee research expenditure in the own country. In this study, lagged research expenditure levels incurred by the Tea

Research Institute, Sri Lanka was used. The implicit assumption is that extension expenditure levels incurred by the Tea Research Institute, Sri Lanka, and research expenditure levels incurred by the Tea Research Institutes in the neighbouring countries have an insignificant effect on Sri Lankan tea production.

The second task is to know the length and duration of the lag. There could be long, variable, and uncertain lags in the interval between commencing a research activity and generating useful knowledge, as well as between generating new technology and seeing it being adopted. Further, once research leads to an increase in the stock of knowledge or an improvement in technology, those increases yield a stream of future benefits that continues until the knowledge or new technology becomes obsolete. Several studies have tried to define the theoretical properties of the research time lag. To incorporate this lagged response, simple linear functions (Edwards and Freebairn, 1981), polynomial lags (Cline, 1975 and Davis, 1979), or trapezoidal lags (Huffman and Evenson, 1992) have been used. Polynomial lags could be estimated with or without endpoint restrictions. Araji *et al.* (1995) used a lagged dependent variable and polynomial distributed lags on the research variables with zero endpoint restrictions. Zachariah *et al.* (1989), Fox *et al.* (1992), and Haque *et al.* (1989) used polynomial distributed lags with zero endpoint restrictions. Evenson (1984) argued for an inverted "V" distribution of returns to research. Researcher can impose the lagged distribution or consider it as an empirical question. In this study, geometrically declining lags are incorporated by including a lagged dependent variable in the supply equation as follows.

$$\frac{Q_t}{A_t} = f\left(\frac{Q_{t-1}}{A_{t-1}}, P_t, WL_t, WK_t, RF_t, RES_{t-k}, time_t\right) \qquad (10)$$

The length of lagged response depends upon the commodity and type of research under consideration and is an empirical question. Araji *et al.* (1995) found that the optimal number of lags was eight years for state level research and six years for regional research for potatoes. Fox *et al.* (1992) found that there is a lag of 2 years to 14 years for dairy. Zachariah *et al.* (1989) found that there is a lag of 4 to 11 years for broilers and Haque *et al.* (1989) found that there is a 1 to 8 year lag for laying–hen research. So far, no attempt has been made to evaluate the lag length of tea research. Different lag lengths may correspond to different types of tea research, *i.e.*, short term, medium term and long term research. Therefore, in this study, different lag lengths were examined by testing the goodness of fit and statistical significance of the equation with different research expenditure lags, which correspond to short term, medium term and long term research and the lag length better described by data was chosen.

A variety of functional forms have been used in supply function estimation. Imposing a functional form is crucial if parametric approaches are used. Functional form imposes a particular type of supply–function shift when a research variable is included. A partial logarithmic form may impose a pivotal proportional shift, while a linear form imposes a parallel shift. A proportional shift suggests that both low cost producers and high cost producers get the same percentage benefit and a parallel shift suggests that per unit cost reduction is equal for all the producers.

Furthermore, functional form of supply determines whether diminishing marginal returns to research can be exhibited in the production function, a necessary condition for obtaining a profit–maximizing solution with respect to research. Research that increases the supply level at a decreasing rate is consistent with diminishing marginal returns. While a linear research variable shows that supply level increases with research at a constant rate, both logarithmic and reciprocal research variables show that supply level increases with a decreasing rate.

Considering all these factors in this study, a linear supply function of the following form was used.

$$\left(\frac{Q_t}{A_t}\right) = \beta_0 + \beta_1 \cdot \left(\frac{Q_{t-1}}{A_{t-1}}\right) + \beta_2 \cdot P_t + \beta_3 \cdot WL_t + \beta_4 \cdot WK_t + \beta_5 \cdot RF_t + \beta_6 \cdot \frac{1}{RES_{t-k}} + \beta_7 \cdot time_t \qquad (11)$$

Homogeneity of degree zero in the supply function is maintained by deflating all prices by producer price indices. Research variable too was deflated to account for inflation.

The short run output price elasticity of supply at period t is represented by the $\beta_2 * A_t * P/Q_t$. The short run research elasticity of supply is given by $-\beta_6 * A_t /(Res_{t-k} * Q_t)$. The short run input price elasticities of supply at period t are represented by the $\beta_3 * A_t * WK_t /Q_t$ and $\beta_4 * A_t * WL_t /Q_t$ for capital and labour, respectively. Long run elasticities can be obtained by dividing short run elasticities by $(1-\beta_i)$.

Data and data sources

Data used for estimation of supply function was obtained from a variety of sources. The quantities of raw tea produced in Sri Lanka was obtained from production data. Producer price in Sri Lanka was obtained by dividing the value of tea exports by the quantity of tea exports at the border (International Tea Committee, 1974–1991). Since a national tea supply is estimated, border price was considered as producer price instead of the farm gate price. Research effectiveness for Sri Lanka was approximated by the expenditure of the Tea Research Institute, which includes employee salaries and expenditure on research programs. This was obtained from the International Service for National Agricultural Research report (Pardey and Roseboom, 1989) for the period 1966–1975 and from the Annual Report of the Sri Lanka Tea Board for the period 1976 to 1993. Producer price index was obtained from various years of the IMF's International Financial Statistics Yearbook.

RESULTS AND DISCUSSION

The supply equation was estimated using TSP computer software (version 4.2B) for the period 1978–1993. Since research expenditure data was not available for years prior to 1958, the model was restricted to the period 1978–1993. Results of the estimation are given in Table 2. Wage rate and rainfall were excluded from the model since a statistically significant fit was not observed with these variables. The R^2 value of the estimated equation is 0.75, suggesting that the model explains most of the variation. Since auto–correlation problems were detected with previous estimations, the function was estimated with a correction for auto–correlation. A negative, however statistically insignificant auto–correlation co–efficient (-0.58) was observed.

The t statistics suggest that all the parameter estimates, except for the lagged dependent variable and fertilizer price, are highly significant. The elasticity of current tea supply with respect to current price at the mean of the sample is 0.097. This is a short run elasticity which could be due to intensive

Table 2. Results of the estimation.

Variable	Mean	Parameter estimate	Elasticity at the mean	t stat
Intercept		-0.5044		1.22
Lagged dependent variable (metric tonnes)	209,569	0.3719		0.92
Current tea price ($/kg)	1.7288	0.0810	0.097	2.25
Research lagged by 19 years ($)	967,293	-0.1139	0.055	1.96
Fertilizer price		-0.00007	-0.000	0.30
Time trend		0.0328		2.31
Autocorrelation co-efficient		-0.58		
Durbin Watson statistic		2.47		
Goodness of fit		0.75		

plucking as a response to high price. Previous studies also reported inelastic supply for Sri Lankan tea. Akiyama and Trivedi (1987) reported an elasticity of 0.03 while Adams and Behram (1976) reported an elasticity of 0.15 in the short run and 0.72 in the long run. The model used in this study did not consider the dynamics perfectly, so that price elasticity estimates could have been biased.

The impact of research on production is shown by the co–efficient β_7. Results indicate that the research effect is positive, producing an elasticity of 0.055 at the mean. When compared to elasticities obtained by other researchers (Table 1), this number is low except for Araji *et al.* (1995). Also, results suggest that it takes 19 years to observe the effect of research. This implies that it is due to long term research which includes development of new planting material. Figure 1 shows the impact of research on tea production and its lagged response. The curve attains its maximum at the year 19. Then the curve turns down when the technology depreciates or becomes obsolete and is progressively abandoned by the industry.

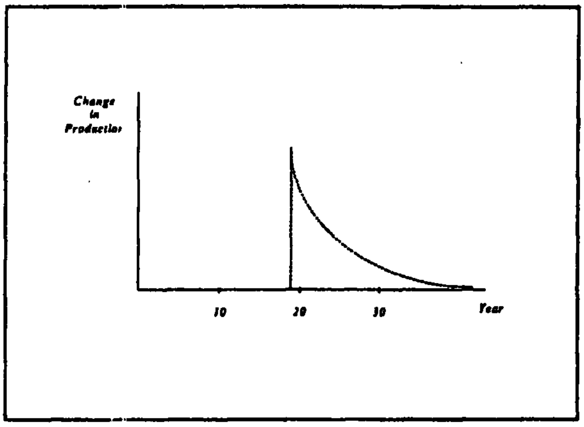

Figure 1. **The impact of research on productivity.**

The elasticity of supply with respect to fertilizer price is negative as expected, but is insignificant. During the sample period, there is an increasing trend in tea production as shown by the co–efficient β_{8}.

CONCLUSIONS

The conclusion drawn from this study is that research has a statistically significant positive impact on tea production in Sri Lanka. Furthermore, current tea production responds positively to the tea price and negatively to the fertilizer price. Even though further research is necessary to confirm these findings, the implication is, Sri Lanka could have increased its quantity produced by increasing in investment in tea research 19 years in advance.

The implicit assumption in this study is the perfect knowledge transmission. Further research is necessary which relaxes this assumption and include extension as an explanatory variable in the tea supply function.

This study used a static model to describe the supply response of tea. Since tea is a perennial crop, supply response should be modeled considering the dynamic aspects of production, *i.e.*, by assuming producers maximize profits over infinite horizon (Akiyama and Trivedi, 1987). Further research is necessary to include the impact of research on such dynamic models.

Even though the results show that research has a positive impact, no attempt has been made in this study to determine its cost effectiveness. Further research is necessary to calculate the net returns from tea research considering the distortions due to tea export tax.

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