
THE CONTRIBUTION OF TURMERIC RESEARCH AND DEVELOPMENT IN THE ECONOMY OF BANGLADESH: AN EX-POST ANALYSIS

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Abstract

The study estimated the benefit and rates of returns to investment on turmeric research and development in Bangladesh. The Economic Surplus Model with ex-post analysis was used to determine the returns to investment and their distribution between the production and consumption. Several discounting techniques were also used to assess the efficiency of turmeric research. The adoption rate was found increasing trend over the period. The yield of BARI developed modern varieties of turmeric was 41 to 73% higher than those of the local variety. Society got net benefit Tk. 9333.88 million from the investment of turmeric research and extension. The net present value (NPV) and present value of research cost (PVRC) were estimated at Tk. 1200.84 and 157.88, respectively. The internal rate of return (IRR) and benefit cost ratio (BCR) were estimated to be 68% and 10.45, respectively indicated investment on turmeric research and development was a good and profitable investment. Seed production programme of turmeric should be taken largely to increase production by increasing area adoption.

Keywords: Turmeric, Contribution, Adoption, Yield Advantage, Benefit and Rate of Return

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Introduction

Turmeric is a spice derived from the rhizome of *Curcuma longa* L. which is used as condiment, flavouring and colouring agent, drug and cosmetic in addition to its use in social and religious ceremonies. It is a principal ingredient in the Bangladeshi kitchen as curry powder and paste. It adds flavour and colour to curries and has medicinal values also. In 1984-85, just before development and introducing of improved varieties of turmeric in Bangladesh yield per hectare was very low and it was only 1.92 tonnes per hectare. Yield per hectare of turmeric started to increase since 1985-86 and it stands 5.16 tonnes per hectare in 2007-08 production period, due to develop and dissemination of improved varieties of turmeric (BBS, 2012).

Due to increasing population, demand for cereal food increased significantly. To mitigate this demand, the land of turmeric crops is being diverted to cereal food crop cultivation. On the other hand, now-a-days many spice-processing industries such as Square, BD Foods, Pran, Archu, Advanced Chemical Industries (ACI), Amrita, Dekko etc. have been established in Bangladesh. They are exporting turmeric as a finished product outside the country. Due to that, demands for turmeric as raw material of these industries are increasing with the extension of their production. That is why; the total demands for turmeric are increasing at incremental rate. Resulting that, a big gap was observed between production and demand now. To meet up this gap the country has

to spend a huge amount of foreign currency in every year for importing spices from abroad.

Realizing the importance of turmeric, Bangladesh government started turmeric research through Horticulture Division of BARI since 1980-81 for increasing turmeric production. But the fund was not sufficient to do research vastly. To keep the continuity of research of turmeric and other spices, Bangladesh government established Spices Research Centre (SRC) in 1994 under Bangladesh Agricultural Research Institute (BARI) for increasing the production of turmeric throughout the country. BARI has already released three improved turmeric varieties namely BARI Turmeric- 1, 2, and 3. These varieties are cultivated in the farmers' fields since the release of these varieties. BARI, BARC (Bangladesh Agricultural Research Council) and DAE (Department of Agricultural Extension), to some extent have strengthened their works to turmeric production. However, for the research work of turmeric and its development, the contribution of BARC and DAE are greatly associated with BARI.

The present analysis thus took into the benefits from past turmeric research and its farm level development in the country. However, this study provided information for the policy makers, donors, researchers, extension people and the public on the contribution and the rate of return to investment in turmeric research in Bangladesh.

Methodology

Sources of data

For the present study, data were collected from different sources like published and unpublished reports, and informal scientist's interview. The area, production and yield of BDMVs (BARI Developed Modern Varieties) of turmeric were collected from SRC (Spices Research Centre); adoption rates were collected through informal scientist's interview; and harvest price and consumer price index (CPI) were collected from various issues of Statistical Yearbooks (1985 to 2012) published by the Bangladesh Bureau of Statistics. The supply elasticity was taken from the study conducted by Dey and Norton (1993). Since SRC of BARI is the main organization for turmeric research, the research cost included mainly from SRC of BARI. The extension and promotion activities were done by DAE and the related costs were collected from this organization. BARC mainly provided the administrative costs. The on-farm yield data of BDMVs turmeric varieties were collected from the SRC, Bogra. Data on the input cost change was calculated by the researcher through analyzing increased production claimed higher labour costs for harvesting and transporting, expensive of seeds, and used slightly more fertilizers per hectare for improved variety than for traditional varieties.

Analytical procedure

The collected data were analyzed using the following statistical techniques.

Estimation of returns to investment

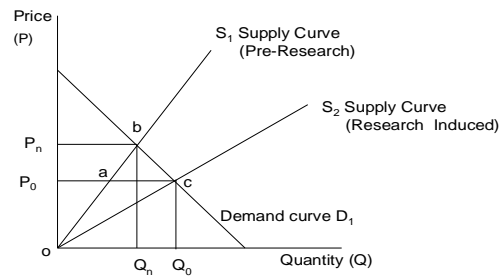
The Economic Surplus Model (ESM) with Ex-Post analysis was used to estimate the rate of returns to investment in turmeric research and extension. The analysis was done under small open-economy market situation. The theoretical concept of ESM has been illustrated below.

Theoretical concept of Economic Surplus Model (ESM): The concept of economic surplus was used to measure economic welfare and the changes in economic welfare from policy and other interventions (Alston *et al.*, 1995; Currie *et al.*, 1971). Usually the economic surplus concept is adopted to estimate the benefits from the adoption of improved varieties. The components of economic surplus are consumer surplus and producer surplus. Given the initial condition (i.e., pre-research supply curve S_1 and demand curve D_1), consumer surplus is depicted as Area P_0P_nb in Fig. 1. This is the surplus or benefit to consumers because of a functioning market. Consumer surplus is that area beneath the demand curve less the cost of consumption. The cost of consumption is the area below the price line P_n . Producer surplus is defined by area P_nbO in Fig. 1. Area P_nbO in the surplus left to the farmers after they have paid for the total costs of production, area ObQ_n (Alston *et al.*, 1995).

The adoption of an intervention by farmers, such as an improved variety usually means one of two

things: (i) A farmer can supply more of the commodity using the same level of resources (i.e., same land area and other inputs), or (ii) A farmer can supply the same level of commodity output but do it with fewer resources.

In either case, this is depicted by a shift to the right of the supply curve as shown in Fig. 1 (the shift is from S_1 to S_2). The shift in the supply curve from the adoption of an intervention changes the initial equilibrium price and quantity of the commodity. This new price quantity equilibrium increases economic surplus. The change in economic surplus (economic benefits) is measured by comparing the difference in economic surplus between the pre-adoption period and the post-adoption period.



$$\begin{aligned} \text{Change in Consumer Surplus} &= \text{Area } abc + \text{Area } P_nbP_0 \\ \text{Change in Producer Surplus} &= \text{Area } Oac - \text{Area } P_nbP_0 \\ \text{Change in Total Economic Surplus} &= \text{Area } abc + \text{Area } Oac \end{aligned}$$

Fig. 1. Economic Surplus Model (Closed Economy)

Given a shift in the supply curve S_1 to S_2 , the change in consumer surplus is depicted in Fig. 1 as Area $abc + \text{Area } P_nbP_0$. The shift in the supply curve (due to the adoption of an intervention) has decreased the price consumers now have to pay for the commodity.

Given a shift in the supply curve S_1 to S_2 , the change in producer surplus is depicted in Fig.1 as Area $Oac - \text{Area } P_nbP_0$. Area Oac represents the decrease in the cost of production the same unit of the commodity that farmers now enjoy because they are using the intervention. This represents the benefits to the farmers from adopting the intervention and can be measured and quantified in monetary terms. The adoption of the intervention, however, has increased the quantity produced thereby decreasing the price of the commodity (P_n to P_0 in Fig. 1) and is a loss to farmers income. Farmers can recover some of this loss since they can sell more quantity (Q_n to Q_0 in Fig. 1) of the commodity.

The total social benefits to society from the adoption of an intervention is the summation of the change in consumer surplus plus the change in producer surplus (Area $abc + \text{Area } Oac$) minus the input cost change from adopting the new interventions.

For a closed economy model, the estimated price elasticity of demand is used in the above formulas. For small open-economy model where the elasticity of demand is perfectly elastic, use a sufficiently large number of η (Nagy and Alam,

2000). A small open economy market is one where the amount of exports or imports is small relative to total world trade in the commodity. Thus, there is little or no effect on the world price of the commodity (the small country assumption). In this case, the price of commodity does not change with the shift in the supply curve. For this study, the Bangladesh turmeric market is modelled as a small open economy market.

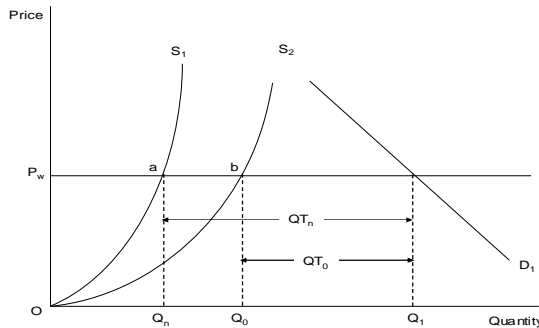


Fig. 2. Small Open-economy Importer Economic Surplus Model

The change in economic surplus for a small open-economy that is domestically produced but allows imports to cover shortfall (i.e., the Bangladesh turmeric market) is depicted Fig. 2. The world price P_w and quantity demanded by Bangladeshi

consumers Q_1 defines the initial equilibrium. At price P_w , producers supply Q_n amount of turmeric when faced by the pre-research supply curve S_1 . Turmeric imports are equal to QT_n . When faced by the research induced supply curve S_2 (the supply curve that exist because farmers have adopted new high yielding varieties). Turmeric producers increased production to quantity Q_n and increase Q_nQ_o . Spices imports are decreased by the same amount as the increase in production Q_nQ_o and are now at QT_o . Since P_w does not change (small economy assumption), there is no change in consumer surplus- consumers are neither better off nor worse off. The enter change in economic surplus from the adoption of new turmeric varieties is thus a change in producer surplus only and is identified by area oab in Fig. 2 (corresponds to area oac in Fig. 1). The amount of foreign exchange saved by the adoption of improved varieties is equal to $P_w \times (Q_nQ_o)$.

Empirical approach: The Akino and Hayami (1975) approximation formulas for calculating changes to producer and consumer economic surplus are described below and these are used in this study. The Akino and Hayami (1975) approximation formulas for calculating the change in economic surplus for a closed economy analysis (Fig. 1) is as follows:

$$\begin{aligned} \text{Area A (abc)} &= 0.5 P_o Q_o ((k(1 + \gamma))^2 / (\gamma + \eta)) & (1) \\ \text{Area B (Oac)} &= k P_o Q_o & (2) \\ \text{Area C (P_nbaP_o)} &= ((P_o Q_o k (1 + \gamma)) / (\gamma + \eta)) \times (1 - ((0.5k(1 + \gamma)\eta) / (\gamma + \eta)) - 0.5k (1 + \gamma)) & (3) \end{aligned}$$

Where,

- P_o = Price of turmeric (Tk./ton) (Existing market price)
- Q_o = Production of BDMVs turmeric (ton) (Existing production)
- P_n = Quantity price that would exist in absence of research
- Q_n = Quantity of the turmeric produced that would exist in absence of research
- k = Horizontal supply shifter
- γ = Price elasticity of turmeric supply
- η = Absolute price elasticity of the demand for the commodity.

The supply shifter (k): The supply shifter 'k' is the overall yield advantage of improved varieties of turmeric over the local variety weighed by the area sown to the improved varieties of turmeric. In the case of the Akino and Hayami (1975) approximation formulas, k is the horizontal shift. The supply shifter k is calculated as follows:

$$k_t = \sum_{i=1}^n [1 - \frac{Y_{it}}{Y_t}] \times A_{it}$$

Where,

- Y_{it} = Yield of the improve varieties of turmeric in year t
- Y_t = The yield of a base (or average yield of local variety turmeric) that has been grown in the past and that would still be grown if no new varieties had been developed
- A_{it} = The proportion of the total area sown to improved varieties of turmeric in year t
- n = The number of improved turmeric varieties

Estimation of net present value (NPV)

The amount of total funds returned from the investment in research is called NPV. The benefits were calculated by using the following formula of NPV:

$$NPV = \left[\sum_{t=1}^n (TSB_t - C_t)(1 + r)^{-t} \right]$$

Where,

- C_t = The cost of research and extension investment in year t
- r = The discount rate
- n = The time horizon over which the benefits of the research investments are realized

Internal rate of return (IRR)

The IRR was calculated relating to the total social benefit (TSB) minus an input cost change, if any, in each year to the research expenditure (C) in each year and is the discount rate that results in a zero net present value of the benefits. The IRR is calculated as

$$0 = \left[\sum_{t=1}^n (TSB_t - C_t)(1 + IRR)^{-t} \right]$$

The IRR can be defined as the rate of interest that makes the accumulated present value of the flow of costs equal to the discounted present value of the flow of returns, at a given point in time (Peterson, 1971).

Results and Discussion

Adoption status and yield advantages of BARI developed modern varieties of turmeric

The adoption of improved variety is very important factors by which the volume of change in economic surplus is determined. The more the adoption of improved varieties over traditional one, higher the change in surplus will be. Apart

from this, it gives us feedback as to why and how well a technology is being accepted by the farmers. There was no turmeric varietal adoption survey conducted in Bangladesh. The existing variety survey information along with the considerable field experience of the spices scientists is used to sketch out the per cent area sown by variety grouping which are presented in Table 1.

Three modern varieties of turmeric named BARI Turmeric-1, BARI Turmeric-2 and BARI Turmeric-3 were released from BARI. BARI Turmeric-1, BARI Turmeric-2 were released in the same year 1984-85 but BARI Turmeric-3 was released in 1998-99. The overall area coverage of BARI Turmeric-1 increased from 0.50 per cent in 1985-86 to 22 per cent in 2007-08 but BARI Hodud-2 increased from 0.50 per cent to 21 per cent over the years. On the contrary of another modern variety BARI Turmeric-3, the area coverage increased from 1 per cent in 1999-2000 to 13 per cent in 2007-08. Area covered by all BDMVs of turmeric occupied about 56 per cent of the area sown to turmeric (Table 1).

Table 1. Area of traditional variety replaced by BMVs of turmeric

Year	Total turmeric area		Area of LVs of turmeric		Area covered by BARI Turmeric-1		Area covered by BARI Turmeric-2		Area covered by BARI Turmeric-3		Area covered by all BMVs of turmeric	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
1979-80	13899	100	13899	100	0	0.00	0	0.00	0	0.00	0	0.00
1980-81	14251	100	14251	100	0	0.00	0	0.00	0	0.00	0	0.00
1981-82	14599	100	14599	100	0	0.00	0	0.00	0	0.00	0	0.00
1982-83	14080	100	14080	100	0	0.00	0	0.00	0	0.00	0	0.00
1983-84	14162	100	14162	100	0	0.00	0	0.00	0	0.00	0	0.00
1984-85	15049	100	15049	100	0	0.00	0	0.00	0	0.00	0	0.00
1985-86	15202	100	15050	99	76	0.50	76	0.50	0	0.00	152	1.00
1986-87	16160	100	15837	98	162	1.00	162	1.00	0	0.00	324	2.00
1987-88	16051	100	15409	96	321	2.00	321	2.00	0	0.00	642	4.00
1988-89	15773	100	14827	94	315	2.00	631	4.00	0	0.00	946	6.00
1989-90	16372	100	15226	93	491	3.00	655	4.00	0	0.00	1146	7.00
1990-91	16332	100	14699	90	817	5.00	817	5.00	0	0.00	1634	10.00
1991-92	16285	100	14168	87	977	6.00	1140	7.00	0	0.00	2117	13.00
1992-93	16089	100	13515	84	1287	8.00	1287	8.00	0	0.00	2574	16.00
1993-94	16132	100	12906	80	1613	10.00	1613	10.00	0	0.00	3226	20.00
1994-95	15986	100	12789	80	1758	11.00	1439	9.00	0	0.00	3197	20.00
1995-96	16026	100	12500	78	1923	12.00	1603	10.00	0	0.00	3526	22.00
1996-97	16132	100	12099	75	2097	13.00	1936	12.00	0	0.00	4033	25.00
1997-98	16063	100	11887	74	2088	13.00	2088	13.00	0	0.00	4176	26.00
1998-99	15846	100	11409	72	2218	14.00	2218	14.00	0	0.00	4436	28.00
1999-00	15575	100	10591	68	2336	15.00	2492	16.00	156	1.00	4984	32.00
2000-01	15800	100	9954	63	2686	17.00	2844	18.00	316	2.00	5846	37.00
2001-02	16018	100	9611	60	3043	19.00	2723	17.00	641	4.00	6407	40.00
2002-03	15992	100	9275	58	2879	18.00	3038	19.00	800	5.00	6717	42.00
2003-04	18441	100	9589	52	3688	20.00	3873	21.00	1291	7.00	8852	48.00
2004-05	18939	100	9470	50	3977	21.00	3788	20.00	1705	9.00	9470	50.00
2005-06	20413	100	9594	47	4083	20.00	4287	21.00	2450	12.00	10820	53.00
2006-07	21028	100	9673	46	4416	21.00	4626	22.00	2313	11.00	11355	54.00
2007-08	22008	100	9684	44	4842	22.00	4622	21.00	2861	13.00	12325	56.00

Source: Several issues of BBS

Note: BDMVs- BARI Developed Modern Varieties, LVs- Traditional Varieties and shaded area indicates no improved varieties were released.

Table 2. Adoption rate of BARI developed modern varieties of turmeric

Name of crop	Varietals Name	Adoption rate (%)
Turmeric	BARI Turmeric-1 (1985-86 to 2007-08)	1.06
	BARI Turmeric-2 (1985-86 to 2007-08)	1.05
	BARI Turmeric-3 (1999-00 to 2007-08)	1.58
	Total BDMVs of turmeric (1985-86 to 2007-08)	2.64

The annual adoption rates were estimated to 1.06 per cent for BARI Turmeric-1 (1985-86 to 2007-08), 1.05 per cent for BARI Turmeric-2 (1985-86 to 2007-08) and 1.58 per cent for BARI Turmeric-3 (1999-2000 to 2007-08) as depicted from Table 2. The adoption rate of BARI Turmeric-3 was higher than those of BARI Turmeric-1 & 2 due to attractive colour and higher yield. The table also showed that the adoption rate of all BDMVs of turmeric was 2.64 per cent.

The supply shifter k identifies the amount of production that can be attributed to the varieties improvement research in each year (i.e., the shift in the supply curve). The more the value of supply shifter the more is the shift in the supply curve, resulting higher benefit to the society. The supply shifter is the outcome of the simultaneous force of adoption per centage and yield advantage. It was calculated using the formula discussed in methodology.

Supply shifter k

Table 3. Calculation of the supply shifter (K) of BARI Turmeric over traditional variety

Year	% Area BARI Turmeric-1 replacing LVs	% Area BARI Turmeric-2 replacing LVs	% Area BARI Turmeric-3 replacing LVs	Supply shifter k
1983-84	0	0	0	0
1984-85	0	0	0	0
1985-86	0.5	0.5	0	0.0049
1986-87	1	1	0	0.0099
1987-88	2	2	0	0.0197
1988-89	2	4	0	0.0279
1989-90	3	4	0	0.0337
1990-91	5	5	0	0.0494
1991-92	6	7	0	0.0633
1992-93	8	8	0	0.0790
1993-94	10	10	0	0.0987
1994-95	11	9	0	0.1004
1995-96	12	10	0	0.1103
1996-97	13	12	0	0.1243
1997-98	13	13	0	0.1283
1998-99	14	14	0	0.1382
1999-00	15	16	1	0.1595
2000-01	17	18	2	0.1866
2001-02	19	17	4	0.2087
2002-03	18	19	5	0.2184
2003-04	20	21	7	0.2528
2004-05	21	20	9	0.2691
2005-06	20	21	12	0.2894
2006-07	21	22	11	0.2919
2007-08	22	21	13	0.3082

Table 3 shows each year adoption per centage and supply shifter of turmeric. It was found that the rate of shift gradually increased. The shifter accounted for the yield advantage of BARI developed turmeric varieties over the traditional varieties. The supply shifter of turmeric was found to be 0.308 for the year 2007-08, meaning that 31% more turmeric production was made available during 2007-08 because of farmers' adoption of BARI developed turmeric variety.

Yield advantages: This is very important factor to determine the economic surplus. The higher yield advantage always ensures higher level of economic surplus. Two types of data exist in most

of the less developed countries for good estimation of yield advantage (YA) as well as the aggregate production function shifter. They are on-station yield trial data and on-farm yield data. The on-station yield data is readily available and most often the only reliable source. One of the arguments against using on-station yield trial data is that of superior management practices and techniques are used and therefore, the results may not reflect on the on-farm situation. Another argument placed by different author (Hertford and Schmits, 1971; Ayer and Schuh, 1972; Akino and Hayami, 1975; Scobie and Posada, 1977; Nagy and Alam, 2000) and showed that the yield advantage estimation from

the on-station yield trial data would be biased upward because the estimation might also include the contribution made by inputs such as fertilizer and water. To account for this problem, the estimated yield advantage of new varieties by estimating production functions of yield as a function of new varieties and other inputs. This process requires a substantial data which is not readily available in Bangladesh.

For the present study, on-farm yield trial data were considered as a more reliable source for the

calculation of yield advantage rather than the on-station yield data in Bangladesh. The yield advantages have been calculated for this study following Gardiner *et al.* (1986), Nagy and Furtan (1978) and Nagy (1991).

Developed varieties of Spices Research Centre (SRC) of BARI have replaced the traditional varieties starting in 1985-86 for BARI Turmeric-1 and BARI Turmeric-2 and 1999-00 for BARI Turmeric-3.

Table 4. Yield advantages of improved varieties of turmeric over traditional varieties

Name of turmeric crop	Average (weighted) yield of Improved variety (t/ha)	Average yield of traditional variety (t/ha)	Yield difference (t/ha)	Yield advantage
BARI Turmeric-1	4.123	1.74	2.38	0.578
BARI Turmeric-2	2.946	1.74	1.21	0.409
BARI Turmeric-3	6.476	1.74	4.74	0.731

The weighted yields were calculated by taking the average of the irrigated optimum, late irrigated and non irrigated yield multiplied by the mean of irrigated, late irrigated and non irrigated area of turmeric. Per hectare average yield of high yielding varieties of turmeric i.e. BARI Turmeric-1, 2 and 3 were found to be 4.12, 2.95 and 6.48 tonnes, respectively. In case of traditional variety it was only 1.74 tonnes. Therefore, the yield advantages of BARI Turmeric-1, 2 and 3 over traditional variety were found to be 58, 41 and 73%, respectively (Table 4).

Estimating benefits from turmeric research and extension

This section deals with the estimation of returns to investment in turmeric research and extension using the economic surplus approach. This approach estimates the benefits to agricultural research by measuring the change in consumers' surplus (CS) and producers' surplus (PS) from a rightward shift in the supply curve that is brought about through technological change. It should be mentioned here that aggregate consumers' surplus, producers' surplus and total surplus were calculated by summing up corresponding surpluses of all turmeric rather than summing up from the areas of the model. In order to calculate the net benefits (NB) research and extension expenditures are subtracted from total surplus. All these estimates of benefits are expressed in real term by using 2007-08 constant prices. The rates of return and NB are then discounted using 10% interest rate for obtaining the efficiency of investment. First, the yearly total social benefits are estimated using the small-open economy model (Fig. 2).

This is done by assigning a very high number to the demand elasticity parameter (η) since in a small open-economy model, η is perfectly elastic. The analysis is undertaken for each year 1980-81 to 2007-08 for turmeric.

Turmeric research and extension in Bangladesh are seemed to be continued by three different organizations. The Organizations are Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural Research Council (BARC) and Department of Agricultural Extension (DAE). The turmeric research and extension expenditure comprised the expenditure of three organizations are furnished in the following sequence.

The year wise expenditures behind variety development and dissemination for the new varieties to the farmers of turmeric are shown in Table 5. The expenditures of BARI/SRC and BARC were estimated from 1980-81 to 2007-08. The accumulated expenditures over the years of BARI/SRC and BARC were estimated at Tk. 95.88 and 17.71 million, respectively. Extension expenditures and input cost change were estimated after development of improved variety and they were started since 1985-86. The cumulative expenditures of extension and input cost changes were respectively amounted at Tk. 67.02 and 530.04 million. Over the years, expenditures accruing for BARI/SRC, BARC, DAE and input cost change were Tk. 710.65 million. For the analysis, the current total expenditures were converted to 2007-08 constant prices using the Bangladesh Middle Income Group CPI Index and it was Tk. 987.70.

Table 5. Turmeric research and extension expenditures by sources from 1980-81 to 2007-08

Year	Total BARI/ SRC Research Expenditures (current Taka)	BARC Administrative Expenditures (current Taka)	Total Extension Expenditures (current Taka)	Input cost change (current Taka)	Total Expenditures (current Taka)	Total Expenditures (2007-08 Tk.)
1980-81	125000	124550	0	0	249550	1475139
1981-82	425000	133000	0	0	558000	2854002
1982-83	235000	141900	0	0	376900	1753902
1983-84	200000	885500	0	0	1085500	4599356
1984-85	112500	818050	0	0	930550	3567626
1985-86	164250	634100	220309	281200	1299859	4485540
1986-87	174350	956650	1026029	635364	2792393	8630861
1987-88	187300	539250	1134000	1334500	3195050	9064153
1988-89	177950	562700	1284993	2084397	4110040	10811807
1989-90	284450	819500	1291320	2676577	5071847	12305861
1990-91	635100	746050	1684024	4045322	7110496	15892219
1991-92	755700	1107250	1767249	5555559	9185758	19550597
1992-93	1630450	1346100	1828555	7160137	11965242	25244078
1993-94	2741150	798650	2199600	9512245	15251645	31216936
1994-95	660000	225500	2317525	9992339	13195364	25648035
1995-96	1980000	171400	2238367	11681879	16071645	29921794
1996-97	7788000	261250	2408661	14163300	24621211	45035932
1997-98	8699064	675850	2660407	15545425	27580746	48295222
1998-99	2882220	1181750	2806472	17504089	24374531	40648556
1999-00	1728804	1221000	3312387	20846439	27108630	43055350
2000-01	2132064	1114500	3354363	25919017	32519944	48889658
2001-02	1985280	645000	3424078	30110662	36165019	51292050
2002-03	3334320	173500	3592067	33461606	40561493	54271199
2003-04	3859020	271300	4216270	46743229	55089818	69537802
2004-05	14129808	301300	4854348	53006990	72292446	86086822
2005-06	13091496	442200	5433602	64197231	83164529	93427779
2006-07	11586960	724950	6909080	71413783	90634773	96056526
2007-08	14171520	690350	7058884	82165158	104085911	104085911
Total	95876756	17713100	67022590	530036448	710648890	987704713

Note: \$1.00 =Tk. 80.00

Table 6. Estimation of surplus from turmeric research and extension investments

Year	Change in consumer surplus (Tk.)	Change in producer surplus (Tk.)	Change in total surplus (Tk.)	Total expenditure (Based on 2007-08 Tk.)	Net Benefit (Tk.)
A	B	C	D=B+C	E	F=D-E
1980-81	0	0	0	1475139	-1475139
1981-82	0	0	0	2854002	-2854002
1982-83	0	0	0	1753902	-1753902
1983-84	0	0	0	4599356	-4599356
1984-85	0	0	0	3567626	-3567626
1985-86	0.14	12567323.59	12567323.72	4485540	8081784
1986-87	0.20	18699643.14	18699643.35	8630861	10068782
1987-88	0.39	35892454.42	35892454.81	9064153	26828302
1988-89	0.59	54539682.00	54539682.59	10811807	43727876
1989-90	0.83	76900261.89	76900262.72	12305861	64594402
1990-91	1.49	139643807.17	139643808.67	15892219	123751590
1991-92	1.87	176522118.24	176522120.11	19550597	156971524
1992-93	2.31	219729031.58	219729033.89	25244078	194484956
1993-94	2.63	252430504.29	252430506.92	31216936	221213571
1994-95	1.93	185271298.96	185271300.88	25648035	159623266
1995-96	2.06	198973912.42	198973914.48	29921794	169052120
1996-97	3.49	340896087.72	340896091.21	45035932	295860160
1997-98	4.70	460210029.27	460210033.97	48295222	411914812
1998-99	5.00	492267151.11	492267156.11	40648556	451618600
1999-00	5.40	538506185.99	538506191.39	43055350	495450841
2000-01	4.29	434278640.51	434278644.80	48889658	385388987
2001-02	3.49	358382061.88	358382065.37	51292050	307090016
2002-03	3.59	370955714.75	370955718.34	54271199	316684519
2003-04	8.45	892087989.68	892087998.12	69537802	822550196
2004-05	10.59	1130017034.46	1130017045.05	86086822	1043930223
2005-06	12.18	1316432587.41	1316432599.59	93427779	1223004821
2006-07	10.52	1138926169.57	1138926180.09	96056526	1042869654
2007-08	13.50	1477455192.84	1477455206.34	104085911	1373369295
Total	99.64	10321584882.89	10321584982.52	987704713	9333880272

Note: \$1.00 =Tk. 80.00

The total over years changes in consumers' and producer' surplus were estimated Tk. 99.64 and Tk. 10321.58 million respectively from turmeric research and extension. Consumers' surplus was very much lower compared to producers' surplus due to perfectly elasticity of demand for turmeric in the small-open economy market. The estimated total surplus/total benefits ranged from Tk. 12.57 million in 1985-86 to 1477.46 million in 2007-08 and the total surplus accrued as Tk. 10321.58 million from the turmeric research and extension in Bangladesh. Besides, the total net benefits obtained from turmeric research and extension was Tk. 9333.88 million for the year 1980-81 to 2007-08 (Table 6).

Rate of return to turmeric research and extension

The rates of returns are the indicators which help to estimate the investment efficiency of the research programme. There are many types of measures that can be used to estimate the rates of return. Among them, Net Present Value (NPV) of benefit, External Rate of Return (ERR) and Internal Rate of Return (IRR) was considered as the rates of return to turmeric research and extension investments in Bangladesh. For comparing the net benefits with the total research costs, Present Value of Research Costs (PVRC) was also calculated. All the estimates were calculated at constant (2007-08) prices with 10% discount rate. Table 7 was used to calculate the NPV, PVRC, ERR, IRR and BCR under small-

open economy condition. Under open economy, the producers' benefits were found much higher compared to consumers' benefits since the elasticity of demand for turmeric were very high.

Table 7 revealed that the society was benefited substantially from the investment in spices research and extension in Bangladesh. The NPV of benefit indicates the total social benefit for a country and it was found negative up to 1984-85 and then it was positive. It means that the country did not receive any benefit from turmeric research up to 1984-85 (Table 6). After 1984-85, the country as a whole benefited with a big amount and found increasing trend up to 2007-08. The NPV was found to be Tk. 1200.84 million while PVRC over the period was Tk. 157.88 million for turmeric research and extension investment. The ERR was found to be 1049.50%. This means that the average taka spent on research and extension in turmeric earn return 10% annually from the start of the initial investment (1980-81) and is now paying off at the rate of 1049.50% annually into perpetuity. In the benefit/cost mode, using 10% external interest rate, a one taka investment returned 104.95 taka over the period. The IRR of 68% means that on the average, each taka invested in turmeric research and extension returned 68% annually from the date of the initial investment. It implies that the expenditure on turmeric research and extension (Tk. 157.88 million) could have been borrowed at 68% real rate of interest without incurring loss (Table 7).

Table 7. Estimated rates of returns to turmeric research and extension

Name of crop	Net present value (NPV)	Present value of research cost (PVRC)	External Rate of Return (ERR)	Internal Rate of Return (IRR)	Benefit Cost Ratio (BCR)
	Million taka in 2007-08 constant prices		%		
Turmeric	1200.84	157.88	1049.50	68	10.45

Note: \$1.00 =Tk. 80.00

The benefit cost ratios were found to be 10.45 for turmeric. The value of the parameter clearly indicated that the investment in research and extension of turmeric in Bangladesh is a good investment and highly profitable.

Foreign exchange savings

The yearly increase in production due to research save the country's foreign exchange to a remarkable extends. First, the research induced productions for turmeric for the past years were calculated by multiplying the country's total turmeric production by their respective production function shifter k. Multiplying the

results by world turmeric price, foreign exchange savings was obtained.

Considerable amounts of turmeric are imported in Bangladesh every year to meet the internal demand for increasing population. In 2006/07, the imported value of turmeric was Tk. 148.70 million (BBS 2008). In reality, the amount imported is higher due to the illegal border trade of spices from neighbouring countries. Thus, the increased production attributed to turmeric improvement saved foreign exchange amounting to Tk. 9084.63 million from turmeric research and extension (Table 8).

Table 8. Foreign exchange savings from investment in turmeric research

Year	Import (cif) Price (Taka)	Supply Shifter K (per cent)	Turmeric Production (ton)	Increase in Production from Research (ton)	Foreign Exchange Savings (Taka)
	1	2	3	4=2x3	5=1x4
1986-87	152500	0.0099	34665	343.13	52326879
1987-88	98540	0.0197	34740	686.00	67598076
1988-89	58998	0.0279	35928	1003.14	59183308
1989-90	19455	0.0337	37925	1278.57	24874717
1990-91	20564	0.0494	38780	1915.49	39390074
1991-92	36713	0.0633	41115	2604.02	95602759
1992-93	39686	0.0790	41170	3251.77	129049292
1993-94	41083	0.0987	41990	4145.54	170311411
1994-95	41115	0.1004	39550	3971.42	163285631
1995-96	42093	0.1103	40580	4476.18	188416125
1996-97	36584	0.1243	42140	5236.54	191571573
1997-98	36771	0.1283	41500	5326.49	195858544
1998-99	35063	0.1382	40850	5645.77	197960223
1999-00	35027	0.1595	40875	6520.30	228388340
2000-01	33075	0.1866	42900	8004.13	264734501
2001-02	40688	0.2087	42640	8897.47	362019408
2002-03	37915	0.2184	43820	9570.80	362878682
2003-04	41639	0.2528	70730	17878.51	744444648
2004-05	48141	0.2691	79175	21305.47	1025660930
2005-06	49548	0.2894	92395	26735.56	1324687145
2006-07	51819	0.2919	110000	32107.60	1663787020
2007-08	42561	0.3082	116832	36009.14	1532602974
Total Foreign Exchange Savings:				Tk.	9084632260

Note: \$1.00 =Tk. 80.00

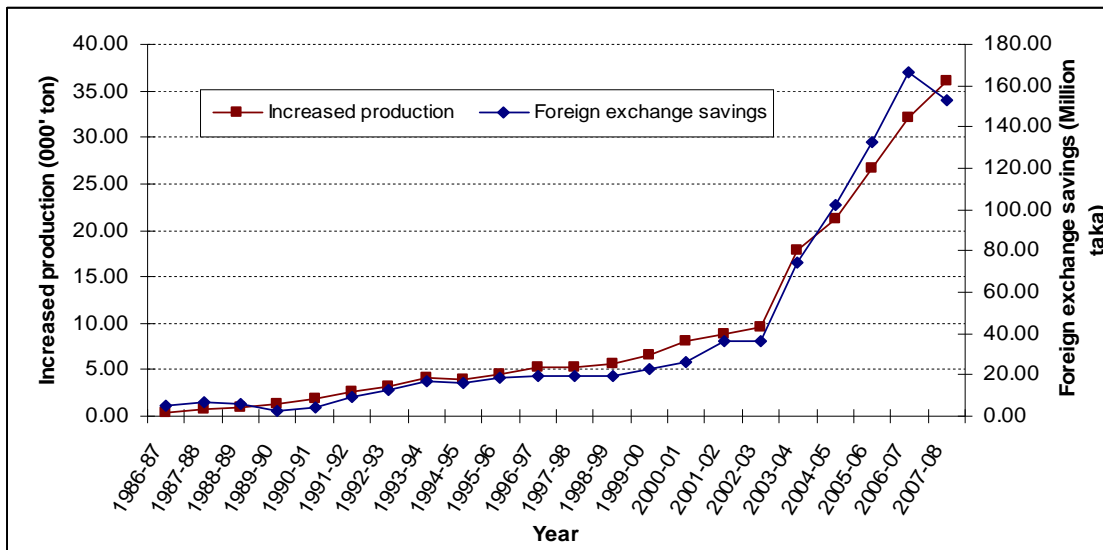


Fig. 3. Foreign exchange savings due to turmeric research and development over time

Policy implications

The empirical results indicate that the expenditure on turmeric research and development paid a favourable rate of returns and the society were also benefited enormously out of it. The IRR to turmeric research and development expenditure was found to be 68%. A 68% IRR on investment in turmeric research and development is a good rate of return. The consumer's surplus is found to be very few only due to small open

economy. But this situation might not be the good sign for the economic prosperity. For the survival of the consumer, price support should be given by government.

The annual adoption rates of BARI Turmeric-1, 2 and 3 are not good because of non availability of seed. Seed production programme should be taken largely by the government and nongovernmental organization so that the farmers can get quality seed easily with a reasonable price.

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