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Research Note

SOCIOECONOMIC DETERMINANTS OF MODERN POTATO VARIETIES ADOPTION AND RESOURCE USE EFFICIENCY IN NORTHERN BANGLADESH

Mst EsmatAra Begum[1]
M. A. Monayem Miah[2]
M. A. Rashid[3]
M. A. Matin[3]
Mohammad Ismail Hossain[1]

ABSTRACT

This study evaluated the determinants of choosing modern potato variety and its' productivitywhile allowing for production inefficiency at the level of individual producers. Results revealed that modern variety selection decisions are influenced positively by younger age and gross return from potato and negatively by a rise in the relative price of seed and wage of labour. Stochastic production frontier results revealed that land,labourand irrigation are the significant determinants of modern potato productivity. The mean level of technical efficiency (TE) is estimated at 82% indicating that farmers can able to increase their yield about 3631kg/ha which is equivalent to Tk41250/ha. Policy implications include measures to increase land reform and keeping potato prices high to boost farm returns and offset the impact of a rise in the labour wage which will synergistically increase the adoption of modern potato as well as farm productivity.

Key words: Adoption, potato varieties, efficiency, Bangladesh

I. INTRODUCTION

Bangladesh has achieved substantial agricultural growth in last two decades through modernization in agricultural practices. Currently, the country is nearly self-sufficient in cereal foodstuff through continuous rise in productivity. On the other hand, though production has increased considerably, the vegetable supply (including potato) still lags the total domestic demand. At present, vegetable sub-sector contributes approximately 3.7% to the national GDP and cultivated area covers 1.8% of total cropped land. Annual per capita consumption of vegetables including potato is extremely low, 86.29 kg/capita/annum in Bangladesh compared to 155 kg in Korea, while the minimum recommended level is 146 kg/capita/annum (FAO, 2007; Hortex, 2013).

[1&2]Senior Scientific Officer and [3] Principal Scientific Officer,[4] CSO, Agricultural Economics Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.
[1] Professor, Department of Agribusiness and Marketing, Bangladesh Agricultural University, Mymensingh-2202

Potato production plays an important role in the economy of Bangladesh becoming one of the major food and cash crops in the country. It ranks third after rice and wheat with respect to food production (8.9 million tons) and area coverage (462 thousand ha) and is cultivated in almost all agro ecological regions of Bangladesh (BBS, 2014). On the one hand, it accounts for 36.51% in total vegetable cropped area of Bangladesh providing economic benefits and creating employment opportunities for the rural poor. On the other hand, it supplements the food consumption of the growing population at lower prices as compared to grains, meat and chicken. The data from developed countries indicate that potatoes have 75%more food energy per unit area than wheat and 58% more than rice. Also, potatoes have 54% more protein per unit area than wheat and 78% higher than rice (Stevenson *et al.*, 2001). Therefore, potato consumption is the best alternative to grains to maintain calorie intake.

The total area and production of potato in Bangladesh during 2013-2014 were 462032 hectares and 8950024 MT respectively. Per hectare yield of potato remained static at around 12.92 MT up to 2000-2001. However, the increased yields of 20.90 MT per hectare during 2013-2014 were mainly due to use of quality seeds of modern varieties and appropriate production technologies (DAE, 2014; BBS, 2014). National average potato productivity is still not good because of low-yielding (11.31 MT/ha) traditional varieties. The composition of area allocated to traditional potato still covers around 35% of the total potato production area (MoA, 2007). Lack of good quality seed at prices affordable by small and marginal farmers and lack of access to irrigation during the growing period of potato crop have been traditionally considered as the binding constraints for continued widespread production of traditional potato, thereby, resulting in lower productivity of potato (Hossain, 1989; Hossain et al., 1990). This is because modern potato varieties are still capable of providing significantly higher yield levels as compared with traditional varieties. For example, the farm-level yield of modern potato varieties is estimated at 20.91 MT/ha as compared to the traditional potato varieties of 11.31 MT/ha, implying productivity gain of 46% in 2013-2014 (BBS, 2014). Therefore, on one hand, there is an urgent need to increase potato production by raising the productivity of the land, which is largely possible by increasing the adoption rate of modern potato varieties. On the other hand, as the government has been trying to diversify food habits and encourage potato consumption to reduce pressure on rice so that farmers will have to generate a large marketable surplus to meet up potato demand of the growing urban population. This implies that Bangladeshi farmers not only need to speed up their adoption rate of modern potato varieties, but also to become efficient and be responsive to market indicators, so that the scarce resources are utilized efficiently, thereby, leading to an increase in potato productivity.

A few studies including total factor productivity growth in modern potato variety (Baset et al., 2009); adoption of recommended potato production technologies (Khalil et al., 2014); and yield and water use efficiency of four potato varieties (Amanullah et al., 2010) were remotely touched the adoption of modern variety of potato in Bangladesh. Furthermore, all of these studies ignored or omitted price factors (both input and output prices) as determinants of technology adoption, which has an important bearing on productivity and resource allocation decisions, and hence provides an incomplete picture of farmers' decision-making processes.

No studies have therefore analyzed the comparative farm level performance, determinants, and factors contributing productivity differentials of modern and traditional varieties of potato. The present study will help fill this gap in Bangladesh.

II. METHODOLOGY

Farm level data generated through household surveys was processed using integrated analytical framework. The study was compared the performance of modern and traditional varietiesgrown by the sample farmers. Thus, paired-t test was used to test the significance in the differences between modern and traditional varieties.

Greene (2006; 2008) proposed an internally consistent method of incorporating 'sample selection' in a stochastic frontier framework which was adopted in this study and is elaborated as follows.Farmers are assumed to choose between modern and traditional potato varieties to maximize profits subject to a set of price and non-price factors. The decision of the i^{th} farmer to choose modern potato is described by an unobservable selection criterion function, d_i^*, which is postulated to be a function of a vector of exogenous output prices, and factors representing farmers' socio-economic circumstances.

The selection criterion function is not observed. Rather a dummy variable, d, is observed. The variable takes a value of 1 for modern potato farms and 0 otherwise. The model is specified as:

$$d_i^* = \gamma' Z_i + w_i, \; d_i = 1 \; (d^* > 0) \quad \text{..... (1)}$$

Where,Z is a vector of exogenous variables explaining the decision to grow modern or traditional potato, $\gamma$is a vector of parameters and w is the error term distributed as $N(0, \sigma^2)$.

The production behaviour of the modern potato farmers is modelled by postulating a restricted stochastic production frontier function as follows:

$$y_i = \beta' x_i + v_i - u_i \quad \text{..... (2)}$$

where $x$represent inputs, $y$represents modern potato output, β are the parameters; and v is the two sided random error, independent of the u, representing random shocks, such as exogenous factors, measurement errors, omitted explanatory variables, and statistical noise; and u is a non-negative random variable associated with inefficiency in production, assumed to be independently distributed as a zero-truncated normal distribution,$u = |U| with U \sim N[0, \sigma_u^2]$.

The 'sample selection bias' arises as a result of the correlation of the unobservables in the stochastic frontier function with those in the variety selection equation (Greene, 2008). In this sample selection framework proposed by Greene (2006, 2008), it is assumed that the unobservables in the variety selection equation is correlated with the 'noise' in the stochasticfrontier model. In other words, w in (1) is correlated with v in (2), and therefore, (v, w) are distributed as bivariate normal distribution with $(v, w) \sim bivariate\ normal\ with\ [(0,0), (\sigma_v^2, \rho\sigma_v, 1)]$. The vectors ($y$, x) are observed when $d = 1$.

Development of the estimator for this model is detailed in (Greene 2006; 2008). The final log likelihood function to be estimated (Greene, 2006):

$$logL_s = \sum_i log \frac{1}{R} \sum_{r=1}^{R} \left\{ I_i \left[\frac{2}{\sigma_u} \emptyset \left(\frac{\beta' x + \sigma_v v_{ir} - y}{\sigma_u} \right) \Phi \left(\frac{y' z + \rho v_{ir}}{\sqrt{1-\rho^2}} \right) \right] + (1 - I_i) \left[\Phi \left(\frac{-y' z - \rho v_{ir}}{\sqrt{1-\rho^2}} \right) \right] \right\} \quad (3)$$

Since the integral of this function does not exist in a closed form, Greene (2006; 2008) proposes computation by simulation. When $\rho = 0$ (that is, the parameter which measures the correlation between w in (1) and v in (2)), the model reduces to that of the conventional stochastic frontier model, and thus provides with a method of testing existence of sample selection bias or selectivity. The model was estimated using STATAVersion 10.

Data and Variables

This study utilized cross-sectional primary data for the crop year 2015. The data were collected by a team of field researcher and Scientific Assistants via an intensive farm survey coordinated by the author. Multistage random sampling techniques were used in selecting study locations as well as the sample farmers. Two districts were initially selected (Bogra and Rangpur) because they have the highest area (57109 ha and 50401 ha respectively in 2013-2014) allocated to potato cultivation. Twelve and 11% of total potato production areas in Bangladesh are represented from these two districts respectively. Of these two districts, twoupazilas were selected based on higher concentration of potato production. Major potato growing villages from twoupazilas were selected with the consultation of the Department of Agricultural Extension (Agriculture Officer). A well-structured and field pre-tested comprehensive interviewing schedule was used for the collection of detailed information on various aspects of the potato crop. Information was obtained on input and output quantities as well as prices, at the plot level. Additionally, socioeconomic characteristics of the farm families were also recorded. A total of 151 potato farmers taking 46 for traditional varieties and 105 for modern varieties were interviewed for this study.

Two sets of variables are needed for this study- one for the probit varietyselection model and the other for the stochastic production frontiermodel. The dependent variable in the probit equation is thefarmers' variety selection criterion. This is a binary variable that takes thevalue of 1 if a plot is planted with modern potato varieties and 0 otherwise. Theexplanatory variables include relative prices of variable inputs (*P'i*) of fertilizers,labour and seed normalised by the price of output (*Py*: potato). Theother variables included in the probit equation are gross returns from potatoproduction per ha, farmer's age, education and farming experience. Before regression analysis, the multicolonearity and autocorrelation were tested and was not found any major serious multicolonearity and autocorrelation based on variance inflation factors (VIF).

All the input and output variables used in the stochastic production frontierwere measured on a per farm basis. The five input variables used in themodel included land, labour, seed, fertilizers and irrigation, andall are expected to have a positive relationship with potato output.

III. RESULTS AND DISCUSSION

Varieties of potato

Cardinal,Diamant, Granola and Asterix are the main HYV/modern varieties grown by farmers in Rangpur and Bogradistricts. Traditional varieties,*SheelBilatee, LalSheel, LalPakri* are

stillwidely grown in the study areas and, although they are lowyielding,bring premium prices abovethose of modern varieties. They arestill popular among growers and consumers,primarily because of their goodkeeping quality in farm potato stores,relatively low costs ofproduction, reasonablyhigh yields with low inputs and understress, and the high market demand due tobetter taste. Usually, farmers follow a different level of production technologies depending upon their infrastructural facilities and socio- economic conditions which ultimately resulting in variability of potato yields (Elias *et al.*, 1992). And the propermanagement of the farm is fully dependent upon ability of the manager, his attitude, knowledge, skill and resource (Hussain and Islam, 1986). However, farmers' production performance depends on physical resources and technology available to them aswell as existing farm management conditions. Therefore, efficient use of inputs and technologies (varieties) can help farmers to get higher production from a given amount of resources.

Production Structure of Potato

Summary statistics for all the variables in Bogra district are presented in Table 1. It is clear from Table 1 that the two categories of growers' cultivated modern and traditional varieties are significantly different with respect to resource use, productivity as well as socio-economic circumstances. Modern potato provides significantly higher yields. Among the prices, the fertilizer price, labour wage, mechanical power, seed price and pesticide price are significantly higher for modern potato producers, whereas potato price is significantly lower in Bogra district. Use of all inputs is significantly higher for modern potato farmers accept fertilizer used. However, growers applied chemicals as a preventive measure rather than for disease treatments and the rate of applications are significantly higher for modern growers. The modern potato growers used almost twice the herbicides, insecticides more than two times. There is no difference in gross returns per ha. Furthermore, among the socioeconomic factors, significant differences exist between modern and traditional potato producers. For example, traditional potato farmers have significantly greater level of age and the length of farming experience. However, there is no difference in the average educational attainments between producers of the different varieties in Bogra district.

Summary statistics for all the variables in Rangpur district are presented in Table 2. It is clear that the two categories of growers' cultivated modern and traditional varieties are significantly different with respect to resource use, productivity as well as socioeconomic circumstances. Modern potato provides significantly higher yields as well as returns. Among the prices, the fertilizer price, the labour wage, mechanical power and seed price are significantly higher for modern potato producers whereas potato price is significantly lower in Rangpur district. Use of land and labour is significantly higher for modern potato farmers whereas use of fertilizer is significantly lower. There is no difference in use of pesticide and irrigation. Furthermore, among the socioeconomic factors, there is no significant difference in the average level of education, age and farming experience between producers of the different varieties in Rangpur district.

Table 1. Summary statistics of the variables in Bogra District

Variable name	Traditional varieties		Modern varieties		Mean difference (MV-TV)	t-ratio
	Mean	Standard deviation	Mean	Standard deviation		
Prices and profits						
Potato price (Tk/kg)	16.90	5.51	11.36	3.31	-5.54	4.41***
Fertilizer price (Tk/kg)	1.99	0.96	3.10	1.05	1.11	4.45***
Labour wage (Tk/person-day)	16.87	7.43	22.06	6.16	5.99	2.90***
Mechanical power (Tk/ha)	150.80	69.88	205.29	76.13	54.49	3.01***
Seed price (Tk/kg)	1.62	0.56	2.87	0.89	1.25	7.5***
Pesticide price (Tk/100 ml or gm)	4.77	3.09	6.09	3.29	1.32	1.66*
Gross return (Tk/ha)	218011	84234	220926	48684	2915	0.15
Inputs and outputs						
Potato output (kg/ha)	13225	3983	20173	4542	6948	6.63***
Cultivated land (ha/farm)	0.29	0.25	0.41	0.33	0.12	1.71**
Fertilizers (kg/ha)	16206.41	5351.73	14267.50	6332.16	-1938.91	-1.36*
Labour (person-days/ha)	192.46	42.65	214.69	59.03	22.23	-1.83**
Pesticides (ml or gm/ha)	3304.19	4035.44	7524.28	6200.80	4220.09	3.51***
Irrigation (Tk/ha)	5595.48	1726.64	6657.63	1488.24	1062.15	2.48**
Socioeconomic factors						
Age (years)	47.09	12.58	41.27	12.78	-5.82	1.82**
Education (year of schooling)	1.73	1.64	2.25	2.72	0.52	1.04
Experience in potato production (years)	21.68	13.65	16.64	8.30	-5.04	-1.62*
Observations	22		55			

Note: ***Significant at 1 per cent level (P < 0.01); **Significant at 5 per cent level (P < 0.05).

Table 2. Summary statistics of the variables in Rangpur District

Variablename	Traditionalvarieties		Modernvarieties		Mean difference (MV-TV)	t-ratio
	Mean	Standard deviation	Mean	Standard deviation		
Prices and profits						
Potato price (Tk/kg)	15.96	3.20	11.65	3.20	-4.31	-5.43***
Fertilizer price(Tk/kg)	1.94	1.18	2.80	3.20	0.86	1.68**
Labour wage(Tk/person-day)	14.56	5.19	23.68	24.11	9.12	11.61***
Mechanical power price (Tk/ha)	129.31	35.02	178.94	168.40	49.63	1.20**
Seed price (Tk/kg)	1.68	0.61	2.94	3.57	1.62	2.44***
Pesticide price(Tk/100 ml or gm)	6.42	3.63	7.96	8.04	1.54	1.14
Gross return (Tk/ha)	176386	42638	240632	113526	64246	3.52***
Inputs and outputs						
Potato output (kg/ha)	11233	2611	21034	6679	9801	9.04***
Cultivated land (ha/farm)	0.13	0.05	0.54	0.40	0.41	7.30***
Fertilizers (kg/ha)	18767	6379	16298	5941	-2470	-1.59*
Labour(person-days/ha)	163.71	48.39	183.07	35.88	19.36	1.74**
Pesticides(ml or gm/ha)	6514.18	5762.30	5488.8	3611.75	-1025.36	-0.80
Irrigation(Tk/ha)	2496.98	2001.23	3080.6	1598.68	583.62	1.25

Socioeconomic factors						
Age (years)	45.38	10.78	44.9	11.35	-0.48	-0.17
Education (year ofschooling)	1.92	1.86	2.46	2.74	0.54	1.00
Experience in potato production(years)	14.75	8.26	14.84	7.02	0.09	0.05
Observations	24		50			

Note: ***Significant at 1 per cent level (P < 0.01); **Significant at 5 per cent level (P < 0.05).

Determinants of the Choice of Potato Variety

The chi-squared test statistic in the probit variety selection equation is significant at the 1 percent level, confirming the joint significance of the parameters (Table 3). The Pseudo R-squared is estimated at 0.33. About 83% of the observations were accurately predicted. The gross return generated from potato production is asignificant determinant of decision to grow modernpotato. Among the prices, a rise in the relative price of seed and labour wage would decrease the probability of choosing modern potato significantly. The marginal effect of these variables are estimated at -0.16 and -0.18 implying that an one percent increase in the price of seed and labour wage will decrease the adoption probability of modern potato by 0.16 and 0.18% (Table 3).This is because modern potato technology is a labourintensive technology (Table 1 and 2) and harvesting,in particular, requires a large amount of labour in a short space oftime, where use of only family labour may not be sufficient. Therefore, a risein the labour cost will significantly depress the adoption of modern potato technology. Table 3 indicates that producers' age negatively influences the adoption of modern potato. It was found to be significant at the 10% level. In other words, younger farmers are more likely to adopt modern potato farming than older farmers. It is due to the fact that at an older age, farmers' volume ofeconomic activities reduced hence they may be unable to pay for technologies. Besides, older farmers haveaccumulated years of experience in farming through experimentation and observations and may find itdifficult to leave such experiences for new technologies.

Table 3. Parameter estimates of the probit variety selection equation

Variables	Probit coefficients		Marginal effects	
	Coefficient	P- values	Coefficient	P-values
Constant	-3.584201	0.000		
Gross return per ha	0.000007***	0.002	0.000001***	0.002
Labour wage	-0.07215***	0.001	-0.183916***	0.000
Seed price	-0.6596417***	0.004	-0.168148***	0.004
Fertilizer price	0.0802787	0.726	0.0204637	0.726
Age	-0.0039194**	0.018	-0.0009991**	0.021
Farmer's education	0.0745251	0.194	0.018997	0.193
Extension contact	0.0557827	0.839	0.0142665	0.839
Model diagnostics				
Log likelihood	-62.47			
Pseudo R^2	0.33			
LR Chi-squared	60.72***			
Accuracy of prediction (%)	82.80			
Number of observations	151			

Note: ***Significant at 1% level (P<0.01); **Significant at 5% level (P<0.05); *Significantat 10% level (P<0.10)

Productivity of Modern Potato

Table 4 presents the results of the stochastic production frontier model corrected for sample selection bias. Both the estimates of σ_u and $\sigma_v$are significantly different from zero at the 1% level. The coefficient on the ρ variable is significantly different from zero at the 1%level, which confirms that serious sample selection bias exists, thereby justifying the use of the sample selection framework.

The results also reveal that the productivity of potato farming increaseswith land area and labourinputs (Table 4). Labour has the highest elasticity value of 0.28, implying that a one percentincrease in labour input used in modern potato cultivation will increase production by 0.28%. The production elasticity of land has been estimated at 0.06.

Factors Explaining Inefficiency

Results from the inefficiency effects model reveal that the negative effect of the level of education on the decision to produce modern potato could probably be linked to the fact that education pulls away householdsfrom farming as it opens up opportunities to engage in off-farm work that are often morerewarding than farming on small pieces of land. Similar results were reported in the past analyses of technical efficiency in Bangladeshi agriculture (for example see Wadud and White, 2000). The age and experience results are poor andmost likely a consequence of older farmers although have more knowledge of their land arealso being less willing to adopt new ideas(Table 4).

Table 4. Parameter estimates of the stochastic production frontier model for modern potato corrected for sample selection bias

Variables	Stochastic production frontier model (Greene's model)	
	Coefficient	P-values
Frontier production function		
Constant	8.441655***	0.000
ln Land	0.0600218**	0.046
ln Fertilizer	-0.1076763	0.116
lnLabour	0.2821319**	0.018
ln Seed	0.1445561	0.155
ln Irrigation	0.0183897	0.182
Model diagnostics		
Log likelihood	-2.196775	0.491
σ_u	0.2493545***	0.001
σ_v	0.0386988***	0.014
γ	0.8656541***	0.000
ρ (sample selection bias, $\rho_{w,v}$)	-0.5787***	0.002
Wald (chi^2)	15.20	
Inefficiency effects model		
Constant	-3.37878	0.656
Age	0.0334953	0.624
Farmer's education	0.0931064**	0.045
Farming experience	0.0184723	0.655
Extension contact	0.1802194	0.804
Number of observations	105	

Note: ***Significant at 1% level (P < 0.01); **Significant at 5% level (P < 0.05);
*Significantat 10%level (P < 0.10).

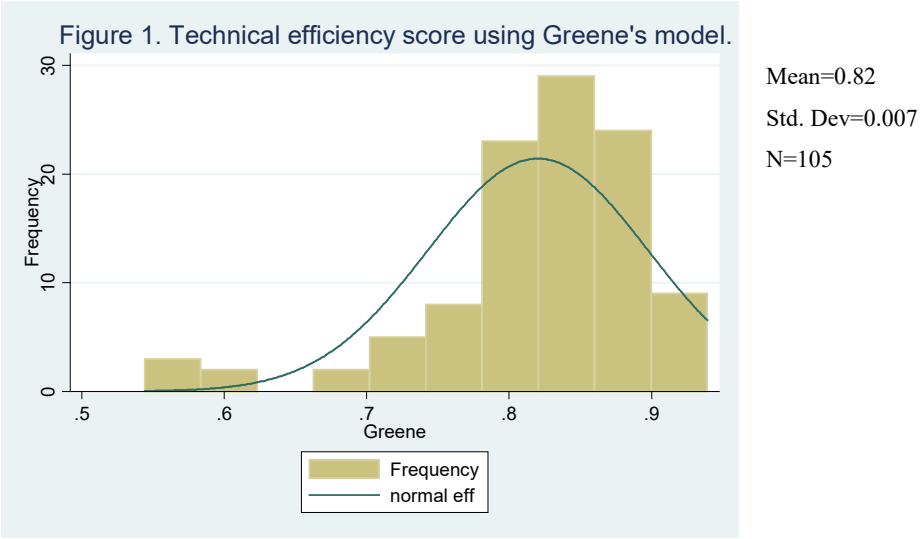
Technical Efficiency of Modern Potato

The summary statistics of technical efficiency scores for modern potato farmers, corrected for sample selection bias, are presented in Table 5. The mean technical efficiency is estimated at 82%, implying that 22% [(100-82)/82] of the production is lost because of technical inefficiency (Table 5 and Figure 1). This implies that the average farm producing modern potato could increase production by 22% (farmers can able to increase their yield about 3631 kg/ha which is equivalent to Tk 41250/ha) through improving technical efficiency, which is substantial. Farmers exhibit a wide range of production inefficiency ranging from 54% to 94% in modern potato farming (Table 5). Seventy two (72.43%) percent of the farmers were operating at efficiency above 80% in Green's model (Figure 1).

Observation of wide variation in production efficiency is not surprising and is similar to the results of Rahman et al. (2009), Bravo-Ureta et al. (2007) and Solis et al. (2007) for developing countries irrespective of the approaches used.

Table 5. Distribution of technical efficiency scores of modern potato farmers (percent)

Efficiency levels	Modern potato
Up to 60%	2.86
61–70%	3.81
71–80%	21.90
81–90%	62.86
91% and above	8.57
Efficiency scores	
Minimum	54.41
Maximum	93.92
Mean efficiency level	82.02
Standard deviation	0.008
Number of observations	105



IV. CONCLUSIONS AND POLICY IMPLICATIONS

The study jointly evaluates the determinants of choosing to modern potatovariety as well as the determinants of modern potato productivity, while allowing for production inefficiency at the level of individual producers, in Bangladesh by applying a sample selection framework in stochastic frontier models.

The results confirm that both price and non-price factors determine the probability of choosing modern potato technology. Gross returns generated from production are the important determinants in choosing modern potato, although lower seed price and labour wagealso matter in the selection decision as well.The returns from modern potato in both districts are significantly higher when compared with traditional potato.Therefore, the higher return of modern potato provides a good incentive to switch, which is further complemented by the availability of seed withlower prices.It also appears thatmodern potato farming is more attractive to younger producers. Results from the stochastic production frontier reveal that land and labour inputs are the main determinants of modern potato productivity. A high level of inefficiency still exists in modern potato production. The mean level of technical efficiency of these self-selected modern potato farmers is estimatedat 82% , implying that there remains substantial scope to increase production by improving technical efficiency alone.The farm specific variables used to explain inefficiencies indicate that those farmerswho have better access to input markets, and those who do less off-farm work tend to bemore efficient.

The policy implications are clear. The adoption of modern potato technology is vulnerable to changesin the relative price of seed and labour, whereas labour input is a significant determinantof modern potato productivity.Therefore, a policy response aimed atincreasing the price of potato would be beneficial from the farmers/producers'perspective, as it would potentially offset any rise in the relative price oflabour as well as keep modern potato production profitable. Another area ofintervention is to increase the availability of land for modern potato cultivation, as it is one of the most important determinants of productivity. Therefore, land reformmeasures aimed at promoting land ownership will have a positive role in increasing productivity of these modern potato farms. It seems that return alone does not fully determine the decision to choose modern potatobecause other price and non-price factors play an important role in determiningvariety selection decisions as well as productivity performance. Nevertheless,given the evidence of this study, policies aimed at raising the modern potatoprice and land reform can be safely suggestedas the way forward to promote adoption of modern potato technology aswell as increase productivity and raise income of the potato farming people as well.

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