DEVELOPMENT OF SUPPLY AND DEMAND FUNCTIONS OF POTATO CROP

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ABSTRACT

The study in hand was carried out to investigate into determinants of supply and demand functions of potato crop in Pakistan. The supply and demand functions of potato crop in Pakistan, specified as a Simultaneous-Equations Recursive(SER) model, yielded the empirical results which revealed that the Domestic Supply ($S_d$) function of potato was determined by domestic price ($P_d$), nutrient-fertilizers used (FNTPO) and credit available (CAT). The domestic demand ($D_d$) has been determined by domestic price ($P_d$), Pakistan’s per capita income (PCI) and Pakistan’s population (POT). The export demand ($E_d$) of potato was influenced by Pakistan’s average export trade price, GDP of the world (GDPWD) and world levels of supply ($S_e$) and export ($E_e$) of potato. Based on empirical results, study recommends that Government has to create such an environment where the producers get due return on their farm investment. Moreover, Government’s input policy should take care of adequate supply of various nutrient-fertilizers, availability at appropriate times and recommended usage at farm level. Similarly, government should allocate sufficient credit for potato producers. In addition, Government investment should be focused on potato research and development and transferring research results to farmers’ fields as envisaged in the ‘Green Box’ of Agreement on Agriculture and other WTO agreements.

Keywords: Supply/Demand Function, Simultaneous-equations recursive model, potato, input policy.


INTRODUCTION

Potato is an important cash crop of Pakistan. In terms of area, its position has improved continuously in the crop sector of Pakistan. On average, the area under potato crop was 47,780 hectares in 1979-85 that has increased to 108,840 hectares during 2001-05. It clearly indicates that the area under potato crop has increased by more than 100 percent over last three decades. This increase is matchless when we compare it with other major crops of Pakistan. One could argue that it is because production of potato and its marketing has been in the hands of private sector and government interference has been minimal as compared to wheat, cotton and other crops, as reported by Zulfiqar (2008 and 2009). Despite the fact that potato is a cash crop with constantly increasing area coverage, no mentionable research has so far been conducted to determine its supply and demand functions. The absence of such type of research constraints the policy decisions on resource use economies and other dynamics of the crop in terms of supply, demand and trade. This scenario has prompted to investigate into determinants of supply and demand functions of Pakistan’s potato crop. For econometric estimation of supply and demand functions, we need to develop domestic supply, domestic demand, export or import supply and export or import demand functions for potato crop.

Objectives of the Study

The main objectives of this study are:

i. To develop and estimate supply and demand functions of potato crop.
ii. To find out major determinants of supply and demand of potato crop.
iii. To recommend policy measures to improve of potato production.

MATERIALS AND METHODS

The following general model of supply and demand was originally attempted and subsequently adjusted in line with economic theory to reach out to the final model:

\[
A = a_0 + a_1A + a_2P_d \quad (1a)
\]
\[
S_d = \beta_0 + \beta_1A + \beta_2FNT + \beta_3PPT + \beta_4WAT \quad (1b)
\]
\[
D_d = \gamma_0 - \gamma_1P_d + \gamma_2GDPP + \gamma_3POPP \quad (1c)
\]
The model (1) of supply and demand is a SER model adopted from Gujarati (2003) and Maddala (2002). The area sown (A) under potato crop is assumed to be determined by lagged area (A\textsubscript{t-1}) and domestic price (P\textsubscript{d}). The so determined area (Â), along with nutrient-fertilizers used, plant protection measures (PPT) applied and water availability (WAT), further determines potato supply (S\textsubscript{d}). It is assumed that the domestic demand (D\textsubscript{d}) is influenced by potato’s own price (P\textsubscript{d}), Pakistan’s Gross Domestic Product (GDPP) and Pakistan’s population (POPP). Export supply (E\textsubscript{d}) is an identity equation equal to S\textsubscript{d} - D\textsubscript{d}. Export demand (E\textsubscript{e}) is assumed to be determined by Pakistan’s export price (P\textsubscript{e}), world trade price of potato (P\textsubscript{w}), world GDP (GDPP) and world population (POPW).

A number of specifications were used and final estimated model was selected on the basis of economic theory and statistical/econometric diagnostics using R\textsuperscript{2}, F-test, t-test, Jarque-Bera (JB) Normality Test, DW test and Durban h tests. These estimated models needed to go through more modifications to make them in a useable form. First, the equation (1a) was Autoregressive functions, which yielded short-run results. It was converted in to its long run version. Second, equations (1b) contained predicted value of area (Â), which was already estimated in equation (1a). Thus, Â in equation (1b) had to be replaced with its estimated values. Third, the model (1) contained export demand function (E\textsubscript{e}) but did not have export supply function (E\textsubscript{d}). The export supply function was computed using Identity equation E\textsubscript{d} = S\textsubscript{d} - D\textsubscript{d}.

The equation (1a) included lagged dependent variables (A\textsubscript{t-1}), used as one of the explanatory variables. This equation provided short-run effects. In order to convert this equation into long run, we computed coefficient of adjustment (λ), and then adjusted short run equation to its long run version. As per Gujarati (2003), we know that coefficient of lagged variable is equal to ‘1 - λ’. So we calculated λ as follows.

\[ 1 - \lambda = \alpha_1 \]

Solving for λ

\[ \lambda = 1 - \alpha_1 \]

For converting equation (1a) into its long run version, we divided all coefficients attached with explanatory variables except lagged variable and constant by the value of (λ) and omitted lagged variable from the equation. This exercise gave us the long run version of equation. As equation (1b) included predicted value of variable ‘Â’, we replaced its value with the long run version of equation (1a).

**Data and Data Sources**

The model (1) applied for determining supply and demand functions of potato crop contained a number of variables. These variables included area and lagged area under potato crop, domestic wholesale price for potato, quantities of potato supplied and demanded, quantities exported and imported, export and import prices of potato, world average trade prices of potato, major inputs like nutrient-fertilizers, pesticides and water used, Gross Domestic Product of Pakistan and Pakistan’s population, world GDP, world population,
Supply And Demand Functions of Potato Crop: Empirical Results

Originally the model (1) was applied to determine the supply and demand functions of potato crop. However, the original combination did not yield results which would have satisfied economic theory and econometric tools. Therefore the model was tried with a number of variations and finally the following model turned out with convincingly good results:

\[ A = 18.46 + 0.50123A_{t-1} + 0.001301P_d + 1.1955TR \]  
\[ (1.954) \] \[ (1.826) \] \[ (1.021) \] \[ (1.069) \] \[ (0.064) \] \[ (0.081) \] \[ (0.318) \] \[ (0.297) \] \[ R^2 = 0.9533 \] \[ F = 149.800 \] \[ DW = 1.9431 \] \[ Durban h^{1} \] \[ N = 26 \]

\[ S_d = -485.39 + 15.349A + 11.435FNTPO + 0.000002CAT \]  
\[ (-3.524) \] \[ (4.379) \] \[ (2.048) \] \[ (1.365) \] \[ (0.002) \] \[ (0.000) \] \[ (0.053) \] \[ (0.186) \] \[ R^2 = 0.9374 \] \[ F = 109.732 \] \[ DW = 1.2831 \] \[ N = 26 \]

\[ D_d = -2.6662 - 0.048992P_d + 0.052187PCI + 3.7324POT \]  
\[ (-0.01021) \] \[ (-3.692) \] \[ (7.075) \] \[ (1.213) \] \[ (0.99200) \] \[ (0.001) \] \[ (0.000) \] \[ (0.238) \] \[ R^2 = 0.9775 \] \[ F = 318.664 \] \[ DW = 1.5269 \] \[ N = 26 \]

\[ E_d = 83.453 - 0.000213P_d + 0.008997GDPWD - 0.0000614S_d - 0.0168E_d \]  
\[ (0.6367) \] \[ (-0.0518) \] \[ (1.093) \] \[ (-1.017) \] \[ (-1.303) \] \[ (0.5310) \] \[ (0.9590) \] \[ (0.071) \] \[ (0.3210) \] \[ (0.207) \] \[ R^2 = 0.3284 \] \[ F = 2.567 \] \[ DW = 1.1891 \] \[ N = 26 \]

(Figures in the 1st & 2nd row parenthesis are t-ratios and p-values, respectively)

Where

- \( A \) = area under potato in ‘000’ hectares
- \( A_{t-1} \) = lagged area under potato in ‘000’ hectares
- \( A \) = area predicted under potato in ‘000’ hectares
- \( S_d \) = domestic supply of potato in Pakistan in ‘000’ tons
- \( D_d \) = domestic demand of potato in ‘000’ tons
- \( E_d \) = net export supply of potato in Pakistan in ‘000’ tons
- \( S_w \) = world level supply of potato in ‘000’ tons
- \( E_w \) = world level export of potato in ‘000’ tons
- \( P_d \) = domestic price in Pak. Rupees per m. ton.
- \( P_e \) = Export price of potato per ton in US$ 
- \( P_w \) = world level price of potato per ton in US$
- \( GDPWD \) = GDP of the world in billion US$
- \( PCI \) = per capita income in Pakistan
- \( POT \) = population of Pakistan in millions 
- \( FNTPO \) = total nutrient-fertilizers in tons used in potato
- \( CAT \) = availability of credit in ’000’ Rupees
- \( TR= \) trend variable, having values 1, 2, 3, 4,..., for the years of observations included

Diagnostic Evaluation

The estimated model fulfilled the economic theory requirements as all of its explanatory variables and possessed correct signs. The lagged area \( (A_{t-1}) \) and potato’s own price \( (P_d) \) positively determined present area under potato \( (A) \), which along with nutrient-fertilizers used \( (FNTPO) \) in potato and credit availability \( (CAT) \) determined supply of potato \( (S_d) \) positively. The domestic demand of potato \( (D_d) \) was negatively influenced by potato’s own price \( (P_d) \) and positively by per capita income \( (PCI) \) of Pakistan and the size of country’s population \( (POT) \). The potato export demand \( (E_d) \) was inversely affected by Pakistan’s export price \( (P_e) \), total world output of potato \( (S_w) \) and volume of world level potato export but positively affected by world’s GDP \( (GDPWD) \). Thus, all variables included in the model behaved according to economic theory.

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1 Durban h could not be computed. (should be inserted in text)
As far as statistical and econometric diagnostic statistics requirements are concerned, the estimated potato supply and demand functions fulfilled such requirements as well. In case of equation (2a), the value of $R^2 = 0.9533$ indicated that 95.33% variations in the dependent variable were explained by variations in explanatory variables included. The value of $F_{stat} = 149.80$ was much higher, relative to $T_{tab}$ (2, 23; 0.05) = 3.40, suggesting that data yielded a good fit. The value of Jarque-Bera (JB) test of Normality was 2.8946 with $p$-value = 0.235. As $p$-value was nearer but not too close to zero, one cannot say for sure about normality of residuals. The explanatory variables ($A_{i,j}$) included in equation (2a) was statistically significant on the basis of t-ratio and $p$-value = 0.081 where as variable ($P_{d,j}$) was significant only at $p$-value = 0.318. The DW was 1.9431, which remained within critical region, reflecting no problem of Auto-correlation. Although, the equation was auto-regressive but model did not compute Durban h. The 14 runs (positive = 11 & negative = 15) fell within the critical region (8, 19), again suggesting no autocorrelation problem.

In the similar fashion, the values of $R^2$ (0.9374 & 0.9775) and F statistic (109.732 & 318.664) for equations (2b & c) were quiet high. $R^2$ (0.3284) and F statistic (2.567) of last equation (2d) was not reasonably high; however, F statistic was at 0.068 level significance.

The values of JB tests of the three equations (2b, c & d), respectively, were 1.6775 with $p$-value = 0.432, 0.3068 with $p$-value = 0.858 and 1.3324 with $p$-value = 0.514, that suggested normality of residuals in all cases. DW statistic of equation (2b) was 1.2831, which falls in no decisive zone at 0.05 level of significance ($d_1 = 1.143$ & $d_2 = 1.652$). The runs test (runs = 12; positive = 12 & negative = 14) reinforced that 12 runs fell in critical region (8, 20) and therefore there may not be any autocorrelation problem. The DW of equation (2c) was 1.5269, which falls in no decision zone at 0.05 level of significance ($d_1 = 1.143$ & $d_2 = 1.652$). But at 0.01 level of significance ($d_1 = 0.026$ & $d_2 = 1.411$) it fell within critical region, suggesting no autocorrelation problem. The 12 runs (positive = 14 & negative = 12) fell within the critical region (8, 20), suggesting no autocorrelation. The DW of equation (2d) was estimated at 1.1891, which fell in indecisive zone at 0.05 level of significance ($d_1 = 1.062$ & $d_2 = 1.759$). The 14 runs (positive = 12 & negative = 14) fell within the critical region (8, 20), suggesting no auto-correlation problem.

The explanatory variables ($A_{i,j}$ & $P_{d,j}$) included in equation (2a) were statistically significant at 0.081 & 0.318 significance levels, respectively. Variables $A$, FNTPO and CAT of equation (2b) were statistically significant at $p$-values = 0.000, 0.053 & 0.186, respectively. Equation (2c) included variable $P_a$, PCI & POT, which were significant at $p$-values = 0.001, 0.000 & 0.238, respectively. Equation (2d) included variables $P_a$, GDPWD, $S_a$ & $E_a$; the first variable was highly insignificant while others were significant at $p$-values 0.071, 0.321 and 0.207, respectively.

RESULTS AND DISCUSSION

The estimated Model 2(a – d) appeared to be a good model as it performed best amongst several specifications tried, in terms of usual diagnostic statistics and economic theory. However, this estimated model had to adjustments to make it final useable version. As equation (2a) included lagged dependent variables ($A_{i,t}$), used as one of the explanatory variables included; thus this equation provided short-run effects. To convert this equation into long run, we computed coefficient of adjustment ($\lambda$), and then adjusted short run equation into its long run version as follows;

$$A = 34.1454 + 0.002609 P_d + 2.396896 TR$$

(3a)

$$= 66.5035 + 0.002609 P_d$$

(3b)

Since, equation (2b) included predicted value of variable ‘$A$’, which was nothing but equation (3b), hence, substituting the value of ‘$A$’ in equation (3b) in to equation (2b), the later equation adopted the following form;

$$S_d = 535.3725 + 0.04004 P_d + 11.435 FNTPO + 0.00000205 CAT$$

(3c)

Putting average values of variables FNTPO and CAT (Table 1) and including in the intercept, we can further shortened domestic supply equation (3c), as follow;

$$S_d = 875.657 + 0.04004 P_d$$

(3d)

Similarly, domestic demand ($D_d$) and export demand ($E_d$) functions estimated in equations (2c & d) could be further shortened, as follows;

$$D_d = -2.6662 - 0.048992 P_d + 0.052187 PCI + 3.7324 POT$$

(4a)

$$= 1241.395 - 0.048992 P_d$$

(4b)
ED \equiv 83.453 - 0.00213PE + 0.008997GDPWD - 0.000614SW - 0.0168EW \quad (5a) \\
= 19.87223 - 0.000213PE \quad (5b)

Since, the estimated model (1) lacked export supply (ES) function, which was to be computed as an identity equation (difference between SD and DD); hence:

ES = SD - DD \quad (6a)
= -8178.341 + 1.779103PD \quad (6b)

The adjustments made in equations (3) through (6) represented a full model of Pakistan’s potato crop sector, namely:

SD = 535.3725 + 0.04004PD + 1.435FNTPO + 0.00000205CAT \quad (7a) \\
= 875.657 + 0.04004PD \quad (7b)

DD = -2.6662 - 0.048992PD + 0.052187PCI + 3.7324POT \quad (7c) \\
= 1241.395 - 0.048992PD \quad (7d)

ED = 83.453 - 0.00213PE + 0.008997GDPWD - 0.000614SW - 0.0168EW \quad (7e) \\
= 19.87223 - 0.000213PE \quad (7f)

ES = -8178.341 + 1.779103PD \quad (7g)

Final Model

We further simplified the above model (equations 7a-g), keeping all important choice variables in tact and replacing the values of other variables and adding with respective intercepts as follows.

\begin{align*}
SD &= 875.657 + 0.04004PD \\
DD &= 1241.395 - 0.048992PD \\
ED &= 19.87223 - 0.000213PE \\
ES &= -8178.341 + 1.779103PD
\end{align*}

Table 1. \textit{Mean values of variables involved.}

<table>
<thead>
<tr>
<th>Name of variable</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A = area under potato in ‘000’ hectares</td>
<td>77.80</td>
</tr>
<tr>
<td>A\textsubscript{p} = area predicted in ‘000’ hectares</td>
<td>77.80</td>
</tr>
<tr>
<td>A\textsubscript{t1} = lagged area in ‘000’ hectares</td>
<td>74.95</td>
</tr>
<tr>
<td>SD = domestic supply in ‘000’ tons</td>
<td>1049.00</td>
</tr>
<tr>
<td>DD = domestic demand in ‘000’ tons</td>
<td>1029.30</td>
</tr>
<tr>
<td>ED = net export in ‘000’ tons</td>
<td>19.80</td>
</tr>
<tr>
<td>PD = domestic price in Pak. Rupees per m. ton.</td>
<td>4329.90</td>
</tr>
<tr>
<td>PE = Pakistan level trade price per ton in US$</td>
<td>485.19</td>
</tr>
<tr>
<td>SW = world supply in ‘000’ tons</td>
<td>289610.00</td>
</tr>
<tr>
<td>EW = world export in ‘000’ tons</td>
<td>7004.60</td>
</tr>
<tr>
<td>GDPWD = GDP of the world in billion $</td>
<td>25763.00</td>
</tr>
<tr>
<td>PCI = Per capita income of Pakistan</td>
<td>15352.00</td>
</tr>
<tr>
<td>POT = population of Pakistan in millions</td>
<td>118.66</td>
</tr>
<tr>
<td>FNTPO = nutrient-fertilizers used in potato in ‘000’ tons</td>
<td>29.01</td>
</tr>
<tr>
<td>CAT, credit availability in ‘000’ rupees</td>
<td>4204600.00</td>
</tr>
<tr>
<td>TR= trend variable for the years of observations included</td>
<td>13.50</td>
</tr>
</tbody>
</table>

CONCLUSIONS AND RECOMMENDATIONS

In light of results of the study and to enhance optimal utilization of resources in potato sub sector of agricultural economy of Pakistan, following recommendations are presented.

i. The Government should create such an environment where forces of supply and demand could function freely so that producers could benefit of their investment.

ii. The Government’s input policy should take care of private sector so that adequate supply of various nutrient-fertilizers at appropriate times and at fair price are ensured.

iii. The Government should allocated sufficient credit for potato producers.

iv. The Government investment should be focused on potato research and development in collaboration with private sector and transferring research results to farmers’ fields as envisaged in the ‘Green Box’ of Agreement on Agriculture and other WTO agreements.

The supply and demand functions of Pakistan’s potato crop, specified as a SER model, yielded the
empirical results which revealed that the domestic supply function of potato was determined by domestic price, nutrient-fertilizers used and credit available. The domestic demand has been determined by domestic price, Pakistan’s per capita income and Pakistan’s population. The export demand of potato was influenced by Pakistan’s average export trade price, GDP of the world and world levels of supply and export of potato. To enhance optimal utilization of resources in potato sub sector of agricultural economy of Pakistan, government should take steps for functioning of market forces, adequate supply of nutrient-fertilizers, provision of credit, investment on potato research and development in collaboration with private sector.

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