DEVELOPMENT OF SUPPLY AND DEMAND FUNCTIONS OF PAKISTAN’S SUGARCANE CROP

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ABSTRACT

Sugarcane is one of the major crops of agricultural economy of Pakistan. Although, major crops are contributing almost half of the share of agricultural GDP, there has been no analytic research on supply and demand determinants particularly of sugarcane crop. The available researchers mainly concentrated on cost of production, supply response and demand elasticity. This necessitated for conducting detailed research of Pakistan’s sugarcane crop with the objective to develop supply and demand functions. The simultaneous-equations recursive econometrics model of supply and demand functions developed for sugarcane crop reflects that domestic supply of sugarcane ($S_{dsc}$) is determined by domestic price of sugar ($P_{dsc}$), nutrient-fertilizers used (FNT) and water available (WAT). The domestic demand ($D_{dsc}$) is determined by price of sugar ($P_{dsc}$) and Pakistan’s GDP (GDPP). Unlike other crops, sugarcane is not imported into Pakistan. We have therefore, converted white sugar imports into its cane equivalent; consequently, we have a cane import supply ($I_{isc}$) function, which is determined by Pakistan’s predicted import price of sugar ($P_{ls}$) and Pakistan’s predicted supply and demand of sugarcane ($S_{dsc}$ and $D_{dsc}$). In light of results, it is recommended that (i) supply of various nutrient-fertilizers, their availability at appropriate times and their use on crops in recommended proportions should be given due attention in future input use policy. (ii) efforts should be made for irrigation water conservation and application of irrigation water to its optimal requirement on sugarcane crop for improved productivity of this crop. (iii) Government should invest more on research and development and extension activities to optimize resource use in production of sugarcane crop.

Key Words: Sugarcane crop, supply and demand function, variables, domestic supply and domestic demand


INTRODUCTION

Sugarcane crop occupies a vital position in the agricultural economy of Pakistan. Its area under cultivation has increased over the time. As reflected from time series data, the area under sugarcane crop has increased on average from 896,640 hectares in 1980-85 to 1,059,200 hectares during 2006-09, (Agricultural Statistics of Pakistan, various issues and FAO database). The production of sugarcane crop in Pakistan has been in the business of private producers. However, marketing of sugarcane has mainly been regulated or managed by government in one or the other way (Trading Corporation of Pakistan 2006 and Scott et al. 1990). Akhtar (1999) argued that sugarcane remained protected in Pakistan. WTO (2008) referred that provincial governments maintain sugar support prices in conjunction with the Federal Government. The domestic price for sugar was some 10-15% above import parity in 2005-06 and 2007-08, but some 5% below import parity in 2006-07. Nevertheless, the farmers have been substantially assisted in earlier years by domestic sugar prices being set at some 50-60% above world levels.

Although, crop sector has been contributing almost half of the share of agricultural GDP, there has been little analytic research on supply and demand determinants of these crops. The researchers mainly concentrated on cost of production, supply response and demand elasticity. The studies on cost, supply and demand lack complete information on supply and demand functions. Arifullah (2007) stated that most of the studies on cost of production provide different estimates for the same crop and year due mainly to over or under estimation. Studies on supply response in Pakistan are found in a good number relative to studies on other aspects; these include Falcon (1964), Cumming (1975), Ahmad and Chaudry (1987) and Tween (1986) and Ali (1988). However, sugarcane crop has been covered by only three of these studies i.e. Ahmad and Chaudry (1987) and Tween (1986) and Ali (1988). In addition, these studies do not provide econometrically estimated full production or supply functions, which reflect the major determinants of supply of the crop. On demand side,
fewer studies are available (Cornelisse and Kuijpers, 1987; Ahmad et al. 1987; Hamid et al. 1987; Alderman 1988; Ashfaq, Griffith and Parton, 2001) but none of these covers sugarcane crop. More recently, Hussain, Sofia and Zakir (2006) while analyzing the economics of sugarcane production in Pakistan using Policy Analysis Matrix (PAM) argued that Pakistan has no comparative advantage in producing sugar at export parity prices but suggested that sugarcane crop may be produced as an import substitution crop to meet the sugar industry demand. As far as specific problems confronting supply and demand determinants of sugarcane crop are concerned, there is hardly any research literature available pertaining to Pakistan.

For quantitative and analytic research, we need at least four econometrically estimated supply and demand functions (domestic supply, domestic demand, export or import supply and export or import demand functions) for each crop/commodity to research on. Since no systematic research work has been carried out for development of econometrically estimated functions, there have been thus no mentionable research studies found on price and policy analysis of sugarcane crop. The foregoing deliberations call for conducting detailed research of Pakistan’s sugarcane crop with the objective to develop supply and demand functions. The instant research article based on first author’s PhD research (Zulfiqar, 2008) has focused on this issue. Such type of research would facilitate policy makers to draw up suitable policy measures to improve resource use efficiency in sugarcane crop production.

MATERIAL AND METHODS

The models for determining supply and demand functions explained below contains a number of variables for each of the functions specified. These variables include area and lagged area under each commodity, domestic wholesale price for the commodity, quantities supplied and demanded, quantities imported and export prices, world average trade prices, major inputs like nutrient-fertilizers, pesticides and water used, Gross Domestic Product of Pakistan and Pakistan’s population. The data on most of the listed variables were downloaded from FAO’s website (www.fao.org; statistical databases). In addition, data were also obtained from Government of Pakistan’s publications (Agricultural Statistics of Pakistan’s various issues) and UN databases (comtrade). GDPs related data was collected from IMF database.

Supply and demand functions of sugarcane crop was econometrically estimated using following model of supply and demand and subsequently adjusted according to theoretical response of various determinants.

\[
A = a_0 + a_1A_{-1} + a_2P_d \quad (1a)
\]

\[
S_d = \beta_0 + \beta_1A + \beta_2FNT + \beta_3PPT + \beta_4WAT \quad (1b)
\]

\[
D_d = \gamma_0 - \gamma_1P_d + \gamma_2GDPP + \gamma_3POPP \quad (1c)
\]

\[
I_d = D_d - S_d \quad (1d)
\]

\[
I_i = \theta_0 + \theta_1P_i - \theta_2P_w + \theta_3S_w \quad (1e)
\]

Where:

- \( A \) = area under commodity in ‘000’ hectares
- \( A_{-1} \) = lagged area under commodity in ‘000’ hectares
- \( \hat{A} \) = area predicted under commodity in ‘000’ hectares
- \( S_d \) = domestic supply of respective commodity in Pakistan in ‘000’ M. tons
- \( D_d \) = domestic demand of respective commodity in ‘000’ M. tons
- \( I_d \) = net import demand
- \( I_i \) = net import supply in ‘000’ M. tons
- \( S_w \) = world supply in ‘000’ M. tons
- \( P_d \) = Pakistan’s domestic wholesale price in Pak. Rupees per M.ton.
- \( P_i \) = import price per M. ton in US$.
- \( P_w \) = world trade price per M. ton in US$.
- \( FNT \) = total nutrient-fertilizers in ‘000’ M. tons used
- \( PPT \) = total pesticides used in ‘000’ M. tons
- \( WAT \) = availability of water in million acre feet
- \( POPP \) = population of Pakistan in millions
- \( GDPP \) = GDP of Pakistan

The aforementioned model of supply and demand is a simultaneous-equations recursive model (Gujarati, 2003, Maddala 2002), wherein area sown (A) under crop is assumed to be determined by lagged area (\( A_{-1} \)) and domestic price (\( P_d \)). The so determined area (\( \hat{A} \)), along with nutrient-fertilizers used, plant protection measures (PPT) applied and water availability (WAT), further determines commodity supply (\( S_d \)). The domestic demand (\( D_d \)) is assumed to be influenced by commodity’s own price (\( P_d \)), Pakistan’s national income (GDPP) and size of Pakistan’s population (POPP). Import demand (\( I_d \)) is an identity equation equal to \( D_d - S_d \). Import supply (\( I_i \)) is determined by Pakistan’s import price (\( P_i \)), world trade price (\( P_w \)) and world supply (\( S_w \)) of wheat.

A number of specifications were used and final estimated model was selected on the basis of economic
theory and statistical/econometric diagnostics using $R^2$, F-test, t-test, Jarque-Bera (JB) Normality Test, DW test and Durban h tests. These estimated models needed to go through, at least, three more major modifications to come up to a final usable form. First, the equation (1a) is Autoregressive functions, which yield short-run results; it needed to be converted in to its long-run version. Second, equations (1b) contains predicted value of area (Â), which is already estimated in equation (1a) hence, Â in equation (1b) would have to be replaced with their estimated values. Third, model (1) contains import supply (I$_s$) function but lacks import demand (I$_d$) function, which would be computed as per identity equation I$_d$ = D$_d$ - S$_d$.

As already mentioned, equation (1a) includes lagged dependent variables ($A_{t-1}$), used as one of the explanatory variables included; hence this equation provides short-run effects. To convert this equation into long run, we first compute coefficient of adjustment ($\lambda$), and then adjust short run equation to its long run version. For computation of ($\lambda$), we know that coefficient of lagged variable is equal to \(1 - \lambda\) (Gujarati 2003, pp.673-78).

Hence in case of equation (1a), \(a_1\) is:

\[
1 - \lambda = a_1
\]

Solving for \(\lambda\):

\[
\lambda = 1 - a_1
\]

To convert equation (1a) into its long run version, we would divide all coefficients attached with explanatory variables (with the exception of lagged variable) and constant by the value of \(\lambda\) and omit lagged variable from the equation. By doing so we would get the long run version of equation.

Since equation (1b) includes predicted value of variable ‘A’, hence we would replace its value with the long run version of equation (1a).

RESULTS AND DISCUSSION

Unlike other crops, sugarcane is not imported into or exported from Pakistan. Hence, we can not develop a full model of domestic supply and demand and external trade of sugarcane. We have therefore, converted white sugar imports into its cane equivalent, using prevailing sugar recovery rate (8.7%, average for study period). Consequently, we have a cane import supply (I$_{ssc}$) function in our estimated model.

Our model assumes that, instead of price of cane, sugar price (P$_{dsr}$) determines sugarcane and sugar economy of Pakistan. Hence, sugar prices have been taken as determinants of sugarcane area, supply of sugarcane (S$_{dsc}$) as a consequence and demand of sugarcane (D$_{dsc}$).

Amongst a number of models tried, the following model of supply and demand functions of sugarcane has turned out with reasonably good results relative to all others.

\[
A = 352.41 + 0.55917A_{t-1} + 0.0041876P_{dsr} \\
(2.685) \quad (3.178) \quad (1.236) \quad (0.013) \quad (0.004) \quad (0.229)
\]

\[ R^2 = 0.6184 \quad F = 18.635 \quad DW = 1.6268 \quad Durban h = 1.1773 \quad N = 26 \]

\[
S_{dsc} = -2072.4 + 10.192Â + 4.3560FNT + 0.20343W AT \\
(-0.0989) \quad (0.4467) \quad (1.154) \quad (1.206) \quad (0.922) \quad (0.659) \quad (0.261) \quad (0.241)
\]

\[ R^2 = 0.7171 \quad F = 18.586 \quad DW = 1.9740 \quad N = 26 \]

\[
D_{dsc} = 34442.00 - 0.11033P_{dsr} + 4.6073GDPP \\
(8.841) \quad (-0.2526) \quad (3.161) \quad (0.000) \quad (0.803) \quad (0.004)
\]

\[ R^2 = 0.7186 \quad F = 29.368 \quad DW = 2.1087 \quad N = 26 \]

\[
P_{isr} = -18.407 + 0.93649P_{wsr} \\
(-0.2151) \quad (4.000) \quad (0.832) \quad (0.001)
\]

\[ R^2 = 0.4000 \quad F = 15.999 \quad DW = 0.8189 \quad N = 26 \]

\[
I_{ssc} = -13681.00 + 20.049P_{isr} - 0.46585S_{dsc} + 0.65814D_{dsc} \\
(-1.260) \quad (1.334) \quad (-1.630) \quad (3.334) \quad (0.221) \quad (0.196) \quad (0.1170) \quad (0.003)
\]

\[ R^2 = 0.4009 \quad F = 4.908 \quad DW = 1.6320 \quad N = 26 \]

Where A = area under sugarcane in ‘000’ hectares
A$_{t-1}$ = lagged area under sugarcane in ‘000’ hectares
Â = area predicted under sugarcane in ‘000’ hectares
S$_{dsc}$ = domestic supply of sugarcane in Pakistan in ‘000’ M. tons
S’$_{dsc}$ = predicted domestic supply of sugarcane in Pakistan in ‘000’ M. tons
\[ D_{\text{ds}} = \text{domestic demand of sugarcane in ‘000’ M. tons} \]
\[ I_{\text{ds}} = \text{import of sugarcane (converted from sugar) in ‘000’ M. tons} \]
\[ P_{\text{ds}} = \text{domestic price of sugar in Pak. Rupees per m. ton.} \]
\[ P_{\text{sr}} = \text{import price of sugar per M. ton in US$} \]
\[ P_{\text{wsr}} = \text{world level price of sugar per M. ton} \]
\[ \text{GDPP} = \text{GDP of Pakistan in billion Rupees} \]
\[ \text{FNT} = \text{total nutrient-fertilizers in M. tons} \]
\[ \text{WAT} = \text{availability of water in ‘000’ acre feet} \]

**Diagnostic Evaluation**

The first equation of this model assumes that sugarcane producers’ cane planting behavior is determined by sugarcane lagged area (\( A_{t-1} \)) and domestic price of sugar (\( P_{\text{ds}} \)). Total supply of sugarcane (\( S_{\text{ds}} \)) depends upon predicted area (\( \hat{A} \)), nutrient-fertilizers used (\( \text{FNT} \)) and water availability (\( \text{WAT} \)). Demand of sugarcane (\( D_{\text{ds}} \)) depends on sugar price (\( P_{\text{ds}} \)) and Pakistan’s GDP. Equation (2e) represent import supply (\( I_{\text{ds}} \)) of sugarcane; which depends on predicted import price of sugar (\( P_{\text{sr}} \)), predicted domestic supply of sugarcane (\( S_{\text{ds}} \)), and predicted domestic consumption of sugarcane (\( D_{\text{ds}} \)).

The estimated model fulfills the economic theory requirements as all of its explanatory variables carry correct signs. As far as statistical and econometric diagnostic statistics requirements are concerned, the estimated sugarcane supply and demand functions fulfill all such requirements more satisfactorily than a number of all other specifications tried. In case of equation (2a), the value of \( R^2 = 0.6184 \) indicates that 61.84% variations in the dependent variable has been explained by variations in explanatory variables included. The value of \( F_{\text{estimated}} = 18.635 \) is high enough, relative to \( F_{\text{tabulated}} (2, 23; 0.05) = 3.40 \), suggesting that data yield a good fit. DW statistic is 1.6268, which falls in indecisive zone at 0.05 level of significance (\( d_t = 1.143 \) and \( d_u = 1.652 \)), but being an autoregressive equation, DW is not of much relevance while the model calculated Durban h statistic of equation (2e) estimated at 1.6320, which falls within no autocorrelation zone (\( d_t = 1.1773 \) is valid and shows there is no auto correlation as it falls within critical region (±1.96). The explanatory variable (\( A_{t-1} \)) included in equation is statistically significant on the basis of t-ratios and p-value = 0.004 while variable (\( P_{\text{ds}} \)) is statistically significant at p-value = 0.229.

On the same pattern, the values of \( R^2 (0.7171, 0.7186, 0.4000, \) and \( 0.4009) \) and F statistic (18.586, 29.368, 15.999 and 4.908) for the other four equations (2b-e) included in the model are in acceptable range. DW statistics of equation (2b) is 1.9740, which falls in no autocorrelation zone (\( d_t = 0.928 \) and \( d_u = 1.411 \)). DW statistic of equation (2c) is 2.1087, which falls in no autocorrelation zone at 0.05 level of significance (\( d_t = 1.22 \) and \( d_u = 1.55 \)). The DW of equation (2d) is 0.8189 (\( d_t = 1.30 \) and \( d_u = 1.46 \)), shows auto correlation problem. The DW of equation (2e) is estimated at 1.6320 and falls within no autocorrelation zone (\( d_t = 0.928 \) and \( d_u = 1.411 \)), suggesting no-autocorrelation problem.

The JB test values of equations (2a-e) are respectively 0.3067 with p-value = 0.858, 1.5780 with p-value = 0.454, 22.0092 with p-value = 0.000, 9.5308 with p-value = 0.009 and 1.8372 with p-value = 0.399, which show that two of the equations (namely 2c and d) do not meet the normality of residuals assumption.

As already mentioned, equation (2a) includes lagged dependent variable (\( A_{t-1} \)), used as one of the explanatory variables included; hence this equation provides short-run effects. To convert this equation into long run, we first compute coefficient of adjustment (\( \lambda \)), and then adjust short run equation to its long run version. By doing so we got the following short run version of equation (2a).

\[ A = 790.732 + 0.009499353P_{\text{ds}} \]  \hspace{1cm} (3)

Since equation (2b) includes predicted value of variable ‘\( A \)’, hence substituting the value of ‘\( A \)’ from equation (2a) in to equation (2b), the later equation adopts the following form.

\[ S_{\text{ds}} = 5987.70 + 0.0968173P_{\text{ds}} + 4.356\text{FNT} + 0.20343\text{WAT} \]  \hspace{1cm} (4)

Putting average values of variables FNTWT and WAT (Table I) and including in the intercept, we can further shorten domestic supply of canes equation (4), as follows.

\[ S_{\text{ds}} = 39421.93 + 0.096817P_{\text{ds}} \]  \hspace{1cm} (5)

Similarly, domestic canes demand (\( D_{\text{ds}} \)) function (earlier estimated as equation 2c) can be further shortened, as follows.

\[ D_{\text{ds}} = 34442.31 - 0.11033P_{\text{ds}} + 4.6073\text{GDPP} \]  \hspace{1cm} (6a)

\[ = 43909.85 - 0.11033P_{\text{ds}} \]  \hspace{1cm} (6b)

The import supply of sugarcane equivalent (\( I_{\text{ds}} \)) function, (estimated as equation 2e) can be further shortened, as follows.
The adjustments made in equations (3) through (7) represent a combined model of Pakistan’s sugarcane and white sugar demand and supply functions, namely:

\[
S_{dsc} = 5987.70 + 0.0968173P_{dsr} + 4.356FNT + 0.20343WAT \quad (8a)
\]
\[
= 39421.93 + 0.096817P_{dsr} \quad (8b)
\]
\[
D_{dsc} = 34442.31 - 0.11033P_{dsr} + 4.6073GDPP \quad (8c)
\]
\[
= 43909.85 - 0.11033P_{dsr} \quad (8d)
\]
\[
P_{tsr} = -18.407 + 0.93649P_{wst} \quad (8e)
\]
\[
I_{sc} = -13681.00 + 20.049P_{tsr} - 0.46585S_{d}d + 0.65814D_{d}d \quad (8f)
\]
\[
= 4865.193 + 20.049P_{tsr} \quad (8g)
\]

**Final Model**

Since we are interested in the analysis of various policy scenarios effective under WTO regime, we further simplify the above model (equations 8a - g), keeping all important choice variables in tact and removing all other (irrelevant) variables from the equations and adding with respective intercepts, we get the shorter version of the model, as follows:

\[
S_{dsc} = 39421.93 + 0.096817P_{dsr} \quad (9a)
\]
\[
D_{dsc} = 43909.85 - 0.11033P_{dsr} \quad (9b)
\]
\[
P_{tsr} = -18.407 + 0.93649P_{wst} \quad (9c)
\]
\[
I_{sc} = 4865.193 + 20.049P_{tsr} \quad (9d)
\]

**Table-I**  **Mean values of variables**

<table>
<thead>
<tr>
<th>Name of variable</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A = area under sugar cane in ‘000’ hectares</td>
<td>929.38</td>
</tr>
<tr>
<td>$\hat{A}$ = area predicted in ‘000’ hectares</td>
<td>922.53</td>
</tr>
<tr>
<td>$\hat{A}_{lag}$ = lagged area in ‘000’ hectares</td>
<td>922.53</td>
</tr>
<tr>
<td>$S_{dsc}$ = domestic supply of sugar cane in ‘000’ tons</td>
<td>40835.05</td>
</tr>
<tr>
<td>$\hat{S}_{dsc}$ = predicted domestic supply of sugar cane in ‘000’ tons</td>
<td>40835.00</td>
</tr>
<tr>
<td>$D_{dsc}$ = domestic demand of sugar cane in ‘000’ tons</td>
<td>42299.50</td>
</tr>
<tr>
<td>$I_{dsc}$ = import demand of sugarcane</td>
<td>1464.45</td>
</tr>
<tr>
<td>$I_{sce}$ = import supply of sugarcane</td>
<td>1464.45</td>
</tr>
<tr>
<td>$P_{dsr}$ = domestic price of sugar in Pak. Rupees per m. ton.</td>
<td>14595.77</td>
</tr>
<tr>
<td>$P_{tsr}$ = Pakistan level trade price of sugar per ton in US$</td>
<td>315.70</td>
</tr>
<tr>
<td>$P_{wst}$ = Pakistan level predicted trade price of sugar per ton in US$</td>
<td>315.70</td>
</tr>
<tr>
<td>$P_{wsr}$ = world level trade price of sugar per ton in US$</td>
<td>356.76</td>
</tr>
<tr>
<td>GDPPP, GDP of Pakistan in billion Rupees</td>
<td>2054.90</td>
</tr>
<tr>
<td>FNT, nutrient-fertilizers in ‘000’ tons</td>
<td>2102.60</td>
</tr>
<tr>
<td>WAT, water availability in ‘000’ acre feet</td>
<td>119330.00</td>
</tr>
</tbody>
</table>

Source: derived from the data collected from FAO database, UN database, IMF database and various issues of Agric. Statistics of Pakistan.

**CONCLUSION AND RECOMMENDATIONS**

The simultaneous-equations recursive econometrics model of supply and demand functions developed for sugarcane crop reflects that domestic supply of sugarcane ($S_{dsc}$) is determined by domestic price of sugar ($P_{dsr}$), nutrient-fertilizers used (FNT) and water available (WAT). The domestic demand ($D_{dsc}$) is determined by price of sugar ($P_{dsr}$) and Pakistan’s GDP (GDPP). Unlike other crops, sugarcane is not imported into or exported from Pakistan. We have therefore, converted white sugar imports into its cane equivalent; consequently, we have a cane import supply ($I_{sce}$) function, which is determined by Pakistan’s predicted import price of sugar ($P_{tsr}$) and Pakistan’s predicted supply and demand of sugarcane ($S_{dsc}$ and $D_{dsc}$).

Amongst the various variables determining supply of sugarcane, nutrient-fertilizers and irrigation water seems playing significant role. Therefore, supply of various nutrient-fertilizers, their availability at appropriate times and their use on crops in recommended proportions should be given due attention in future input use policy. Similarly, efforts should be made for irrigation water conservation and application of irrigation water to its optimal requirement on sugarcane crop for improved productivity of this crop.

Government should invest more on research and development and extension activities to optimize resource use in production of sugarcane.
REFERENCES


