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ESTIMATING A SIMULTANEOUS EQUATIONS MODEL FOR THE DEMAND AND SUPPLY OF OYSTER MUSHROOMS (*Pleurotus* Spp.) IN THE RAIPUR, DURG, AND DHAMTARI DISTRICTS OF CHHATTISGARH INDIA

Adarsh Kumar and A.K. Singh
Department of Agricultural Statistics, College of Agriculture, Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India
Corresponding author E-mail: adarshchandrakar279@gmail.com
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ABSTRACT

Chhattisgarh has long been an agrarian state with paddy as its primary crop. In Chhattisgarh, mushrooms are another significant crop. The current work focuses on the oyster mushroom (*Pleurotus* spp.) and estimates simultaneous equation models at their equilibrium point for the markets in the districts of Raipur, Durg, and Dhamtari in Chhattisgarh. Growers, distributors, and consumers of oyster mushrooms (*Pleurotus* spp.) completed surveys that provided the majority of the data used in this study. Model I was determined to be the most effective of the three simultaneous equation models at the supply and demand equilibrium point. The general public favoured soybeans over oyster mushrooms (*Pleurotus* spp.) in this model, whereas Model II was shown to be suitable mainly for customers who had more disposable income than the general public and who favoured chicken over oyster mushrooms (*Pleurotus* spp.).
Keywords : Identification, Reduced form, Two-stage least square, Inflexion point, Simultaneous Equations Model, Equilibrium point.

Introduction

Since its founding, Chhattisgarh has been an agricultural state. The main crop of Chhattisgarh, whose central plains are referred to as the "Rice Bowl of central India," is paddy. Mushrooms, which are actually fleshy, spore-bearing fungus creatures that typically arise above the ground's surface or its source of food and belong to the botanical class Agaricomycetes and order Agaricales, are another interesting crop grown in Chhattisgarh. It is a waste-to-wealth crop with great therapeutic qualities that farmers can readily grow with little infrastructure.

The word "mushroom" can mean different things to different individuals in different nations. They were considered "food of gods" by the Romans and a source of strength for warriors by the Greeks.

Growing mushrooms requires less water and vertical space than other crops. It's a crop that turns waste into wealth. Mushroom growing further supports farmers' livelihoods by offering steady farm income and employment opportunities. It is an indoor crop that doesn't require fertile land and may be grown without sunshine. Because it doesn't require a significant amount of capital, it can also be farmed on a small scale.

The primary data for this study, which focuses on the demand for mushrooms, was gathered from wholesalers' markets and mushroom growers in the same districts. With the exception of disposable income, which was gathered from a few randomly chosen oyster mushroom (*Pleurotus* spp.) customers from the same markets, the majority of the primary data on demand was obtained via wholesalers.

Methods and Materials

200 of the approximately 2000 edible fungus species that have been identified worldwide are found in India. Only six of these species *Pleurotus* spp., often known as oyster or tropical mushrooms, and *Volvariella* spp. are grown in the nation for commercial purposes. (Chinese or paddy straw

mushroom), *Calocybe indica* (milky mushroom), *Agricus bisporus* (European or White-Button mushroom), *Flammulina velutipes* (Enokitake mushroom), and *Lentinus edodes* (Shiitake mushroom). Compared to other mushroom species, *Pleurotus florida* is grown in a larger region and is highly favored by the people of Chhattisgarh.

Table 1: Some common mushrooms, their genus and species found in Chhattisgarh

S. No.	Common Mushroom Name	Genus	Species	Parameter's rank scores (4-highest rank)
1.	Oyster mushroom	*Pleurotus*	*florida, sajor-caju, ostreatus*	*PP: 4, CC: 4, P: 4, A: 4, N: 4, AS: 4, EC: 4 = **28**
2.	Paddy straw mushroom	*Volvariella*	*volvacea*	*PP: 3, CC: 3, P: 3, A: 2, N: 4, AS: 2, EC: 2 = **19**
3.	Milky mushroom	*Calocybe*	*indica*	*PP: 2, CC: 3, P: 1, A: 3, N: 3, AS: 4, EC: 2 = **18**
4.	Button mushroom	*Agricus*	*bisporus*	*PP: 1, CC: 1, P: 4, A: 3, N: 4, AS: 2, EC: 1 = **16**
Note: * PP= production process, CC= cost of cultivation, P= popularity, A= affordability, N= nutritiousness, AS= availability of substrate, EC= environmental condition.				

Based on seven parameters production process (PP), cost of cultivation (CC), popularity (P), affordability (A), nutritiousness (N), availability of substrate (AS), and environmental condition (EC) this study focuses on the oyster mushroom (*Pleurotus* spp.) out of all the aforementioned types of mushrooms.

Collection of Data

The producers, who were primarily from the districts of Raipur, Durg, and Dhamtari in Chhattisgarh, were chosen from the list of producers who were affiliated with and trained by the Mushroom Research Laboratory, Department of Plant Pathology, College of Agriculture and Research Station, Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, C.G. In addition to the producers, information was gathered from a few randomly chosen customers in several markets where the aforementioned producers' goods were being marketed.

The basic data was gathered via telephone interviews or in-person visits to mushroom producers and wholesalers' markets in the same districts. For the interviews with respondents from Raipur, Durg, and Dhamtari, three questions were created.

Method

A simple model of demand and supply:

Demand: $Q = \alpha_1 P + \alpha_2 X + e_d$ (1)

Supply: $Q = \beta_1 P + e_s$ (2)

where, P and Q are endogenous variables, and X is exogenous variables.

The Identification

In a system of M simultaneous equations that concurrently determine the values of M endogenous variables, the estimation of an equation's parameters requires the absence of at least M-1 variables. To put it another way, identifying the simultaneous equations is the most crucial step in estimating their parameters. An equation is considered identified when it is possible to reliably estimate its parameters. An equation is considered unidentified and its parameters cannot be reliably approximated if fewer than M–1 variable is left out.

We need to remove at least M–1=1 variables from an equation in order to find the M=2 equations in our supply and demand model. In simultaneous equations (1-2), P, Q, and X are the three variables in total. The demand equation (1) is unidentifiable and its parameters cannot be consistently approximated because none of the variables are left out. One variable, income (X), is left out of the supply equation (2); as a result, the supply curve is found and its parameter can be calculated.

Before attempting to estimate an equation, the identification condition needs to be verified. Changing the model must be taken into consideration before estimating if an equation cannot be found. However, altering the model shouldn't be done carelessly; no crucial variable should be left out of an equation only for its identification.

The Reduced-Form Equations

The two structural simultaneous Equations (1) and (2) can be solved to express the endogenous variables P and Q as functions of the exogenous variable X and this reformulation of the model is called their reduced form given below as Equations (5) and (8).

This reduced form is very important in its own right, which helps in understanding the structural Equation system. To find the reduced form, we solve (1) and (2) simultaneously for P and Q.

To solve for P, we equate the equations corresponding to the equilibrium quantity, Q, of both the demand and supply, as in Equation (3):

$$\beta_1 P + e_s = \alpha_1 P + \alpha_2 X + e_d \quad (3)$$

$$\Rightarrow P = \frac{\alpha_2}{\beta_1 = \alpha_1} X + \frac{e_d - e_s}{\beta_1 - \alpha_1} \quad (4)$$

$$= \pi_1 X + v_1 \quad (5)$$

To solve for Q, substituting the value of P from (4) into the supply Equation (2):

$$Q = \beta_1 P + e_s$$

$$= \beta_1 \frac{\alpha_2}{(\beta_1 - \alpha_1)} X + \frac{e_d - e_s}{(\beta_1 - \alpha_1)} + e_s \quad (6)$$

$$= \frac{\beta_1 \alpha_2}{(\beta_1 - \alpha_1)} X + \frac{\beta_1 e_d - \alpha_1 e_s}{(\beta_1 - \alpha_1)} \quad (7)$$

$$= \pi_2 X + v_2 \quad (8)$$

The parameters π_1 and π_2 in (5) and (8) are called reduced-form parameters. The error terms v_1 and v_2 are called reduced-form errors.

Two-Stage Least Squares Estimation (2SLS):

i. Least squares estimation of the reduced-form Equation for P and the calculation of its predicted value, $\hat{P}$.

ii. Least squares estimation of the structural Equation in which the right-hand-side endogenous variable P is replaced by its predicted value $\hat{P}$.

Result and Discussion

Because supply and demand cooperate to determine the quantity and price of goods in the market and reach a certain level of equilibrium, they do so at particular price and quantity coordinates for the target markets, which in this case are Raipur, Durg, and Dhamtari.

Equations (1) and (2) already provide the supply and demand forces as simultaneous econometric models. These models are modified to meet the needs of the current study and are produced below in Equations (9) and (10), which explain the quantity and price behaviors of oyster mushrooms in the Raipur, Durg, and Dhamtari markets according to the equilibrium reached in each market.

$$\text{Demand: } Q = \text{Int.} + P + PS + DI \quad (9)$$

$$\text{Supply: } Q = \text{Int.} + P + PF \quad (10)$$

To answer the simultaneous equations model Equations (9) and (10), the market determined two oyster mushroom substitutes, namely chicken and soybeans. As a result, three simultaneous equations with the replacements soybean, chicken, and chicken + soybean combined have been solved.

Identification

In M simultaneous equations, which jointly determine the values of M endogenous variables, at least M–1 variable must be absent from an equation for estimation of its parameters to be possible.

Here in supply and demand model there are M = 2 equations, so require at least M–1=1 variable to be omitted from an equation to identify it. There are a total of three variables: P, Q, and DI. In the demand Equation none of the variables are omitted; thus, it is *unidentified* and its parameters cannot be estimated consistently. In the supply Equation, one variable, income (DI), is omitted; the supply curve is *identified*, and its parameter can be estimated.

Derived reduce form for the Equation (9) and (10)

Derived reduced form Equation for the simultaneous equations model with soybean substitute commodity are as follows:

Quantity:
25.7925* -0.0154PSCH+ 1.2743DI*** -0.3157PF* (11)

Price:
23.6508+2.3723PS***-3.6457 DI***+2.2103PF*** (12)

Derived reduced form Equation for the simultaneous equations model with chicken substitute commodity are as follows:

Quantity:
10.3117*+0.7774PS***+0.5248DI**-0.3510PF** (13)

Price:
37.4930 -0.1331PSCH -1.3606DI*+ 2.2958PF*** (14)

Derived reduced form Equation for the simultaneous equations model with soybean + chicken substitute commodity are as follows:

Quantity:
9.5583+0.7793PS***+0.0045PSCH+0.5231DI**-0.3500PF** (15)

Price:
-11.2774+2.3411PS***-0.0734PSCH-3.6172DI***+ 2.1928PF*** (16)

Fitting simultaneous equations model on demand and supply of oyster mushroom (*Pleurotus* spp.).

The R package's systemfit() model was used to estimate the final simultaneous equations model for Equations (9) and (10) with soybean substitute commodities. The findings are shown in the table below.

Table 2 : Results of analyses of simultaneous equations model with soybean substitute: systemfit() using R

```
> summary(mush.sys)

systemfit results
method: 2SLS

       N DF     SSR detRCov   OLS-R2 McElroy-R2
system 60 53 2149.57  857.29 0.851607    0.86666

    N DF      SSR     MSE    RMSE       R2   Adj R2
eq1 30 26  475.261 18.2793 4.27543 0.934382 0.926810
eq2 30 27 1674.305 62.0113 7.87472 0.768832 0.751708

The covariance matrix of the residuals
       eq1     eq2
eq1 18.2793 16.6202
eq2 16.6202 62.0113

The correlations of the residuals
         eq1      eq2
eq1 1.000000 0.493653
eq2 0.493653 1.000000


2SLS estimates for 'eq1' (equation 1)
Model Formula: q ~ p + ps + di
Instruments: ~ps + di + pf

             Estimate Std. Error  t value   Pr(>|t|)
(Intercept)  6.5555600  5.2045176  1.25959 0.21900739
p           -0.1588154  0.0728058 -2.18136 0.03839073 *
ps           1.1541296  0.2860565  4.03462 0.00042712 ***
di          -0.0541620  0.2560870 -0.21150 0.83414742
---
Signi.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.275427 on 26 degrees of freedom
Number of observations: 30 Degrees of Freedom: 26
SSR: 475.261108 MSE: 18.279273 Root MSE: 4.275427
Multiple R-Squared: 0.934382 Adjusted R-Squared: 0.92681


2SLS estimates for 'eq2' (equation 2)
Model Formula: q ~ p + pf
Instruments: ~ps + di + pf

            Estimate Std. Error  t value   Pr(>|t|)
(Intercept) 10.944682   8.808534  1.24251    0.22473
p           -0.128004   0.134537 -0.95144    0.34982
pf           1.004529   0.170445  5.89357 2.8018e-06 ***
---
Signi.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 7.874725 on 27 degrees of freedom
Number of observations: 30 Degrees of Freedom: 27
SSR: 1674.304724 MSE: 62.011286 Root MSE: 7.874725
Multiple R-Squared: 0.768832 Adjusted R-Squared: 0.751708
```

Thus, from the above results the estimated simultaneous equations results have been given below in Equations (17) and (18).

Model I

Demand:

6.5555 -0.1588 P*+1.1541 PS***-0.0541 DI (17)

Supply:

10.944682-0.1280 P+1.0045 PF** (18)

The final simultaneous equations model for the Equations (9) and (10), with chicken substitute commodity have been estimated by using systemfit() model of the R package, whose results have been presented below in Table.

Table 3 : Results of analyses of simultaneous equations model with chicken substitute: systemfit() using R

```
> summary(mush.sys)

systemfit results
method: 2SLS

       N DF     SSR detRCov   OLS-R2 McElroy-R2
system 60 53 7530.43 551.888 0.480144   0.960408

    N DF      SSR      MSE     RMSE       R2   Adj R2
eq1 30 26  895.721  34.4508  5.86948 0.876329 0.862060
eq2 30 27 6634.708 245.7299 15.67577 0.083958 0.016103

The covariance matrix of the residuals
       eq1     eq2
eq1 34.4508  88.959
eq2 88.9590 245.730

The correlations of the residuals
         eq1      eq2
eq1 1.000000 0.966855
eq2 0.966855 1.000000



2SLS estimates for 'eq1' (equation 1)
Model Formula: q ~ p + psch + di
Instruments: ~psch + di + pf

              Estimate Std. Error  t value   Pr(>|t|)
(Intercept) 30.9480328 15.2213774  2.03320   0.052359 .
p           -0.1375064  0.0963564 -1.42706   0.165463
psch        -0.0337248  0.0750503 -0.44936   0.656893
di           1.0871599  0.1107938  9.81246 3.1399e-10 ***
---
Signi.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 5.869482 on 26 degrees of freedom
Number of observations: 30 Degrees of Freedom: 26
```

```
SSR: 895.721407 MSE: 34.450823 Root MSE: 5.869482
Multiple R-Squared: 0.876329 Adjusted R-Squared: 0.86206
2SLS estimates for 'eq2' (equation 2)
Model Formula: q ~ p + pf
Instruments: ~psch + di + pf

          Estimate Std. Error  t value  Pr(>|t|)
(Intercept) 35.278199  20.821328  1.69433 0.1017089
p         -0.848742   0.426989 -1.98774 0.0570694 .
pf         1.779152   0.492819  3.61015 0.0012292 **
---
Signi.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 15.675775 on 27 degrees of freedom
Number of observations: 30 Degrees of Freedom: 27
SSR: 6634.707644 MSE: 245.729913 Root MSE: 15.675775
Multiple R-Squared: 0.083958 Adjusted R-Squared: 0.016103
```

Thus, from the above results the estimated simultaneous equations results have been given below in Equations (19) and (20)

Model II

Demand:
30.9480-0.1375 P-0.0337 PSCH +1.0871 DI*** (19)

Supply:
35.2781-0.8487 P+1.7791 PF** (20)

The final simultaneous equations model for the Equations (9) and (10), with chicken+soybean substitute commodity have been estimated by using systemfit() model of the R package, whose results have been presented in Table.

Table 4 : Results of analyses of simultaneous equations model with combine substitute (chicken + soybean): systemfit() using R

```
> summary(mush.sys)

systemfit results
method: 2SLS

       N DF     SSR detRCov   OLS-R2 McElroy-R2
system 60 52 2149.62 894.395 0.851603   0.863758

     N DF      SSR     MSE   RMSE       R2   Adj R2
eq1 30 25  476.692 19.0677 4.36666 0.934184 0.923653
eq2 30 27 1672.923 61.9601 7.87147 0.769023 0.751913

The covariance matrix of the residuals
       eq1     eq2
eq1 19.0677 16.9423
eq2 16.9423 61.9601

The correlations of the residuals
        eq1      eq2
eq1 1.000000 0.492909
```

Thus, from the above results the estimated simultaneous equations results have been given below in Equations (21) and (22).

Model III

Demand:
7.7585-0.1595P*+1.1529PS**-0.0072PSCH -0.0541DI (21)

Supply:
10.9220-0.1273 P+1.0038 PF*** (22)

Comparison of the three estimated simultaneous equations model as discussed above

The table below illustrates the percentage contribution of sums of squares attributed to various variables in the three simultaneous equation models: Model I, Model II, and Model III, which primarily differ in their respective replacement commodities.

Table 5 : Percent variation contributed by different variables of the three simultaneous equations model

Source of varia-tion	Simultaneous equations model with soybean substitute Model I	Simultaneous equations model with chicken substitute Model II	Simultaneous equations model with soybean+ chicken substitute Model III
P.Pred	50.05661	48.20649	49.88402
Ps	47.20412	NA	47.37394
Psch	NA	0.035898	0.004142
Di	0.011045	45.79859	0.011045
Resid-uals	2.728227	5.959021	2.726846
Total	**7242.8**	**7242.8**	**7242.8**

Note: NA; it indicates that the corresponding variable source is not present in the model.

From the above Table, it is apparent that the simultaneous equations model vide Equations (17) and (18) (Model I) is the best among all the three models for the reasons enunciated below:

(a) The percent contribution due to soybean substitute of Model I is almost equal to that of Model III.

(b) The percent contribution due to predicted price of Model I is almost equal to that of Model III.

(c) The percent contribution due to chicken substitute of Model II and Model III, both are almost equal to zero.

(d) Predicted price and disposable income are the two main sources of variables that account for the percentage contribution in Model II. Model II is only appropriate for people with high disposable income because the contribution from chicken is essentially insignificant.

(e) In light of the aforementioned considerations, Model I, which substitutes soybeans for oyster mushrooms, is the most appropriate simultaneous equation model for this investigation.

The identification of equilibrium point (E) of demand and supply curves of oyster mushroom (*Pleurotus* spp.) from the markets of Raipur, Durg and Dhamtari districts.

A point of equilibrium is the coordinate of intersection where the demand and supply curves intersect. Identification of this point makes it possible to identify i.e., to be able to estimate the parameters of the simultaneous equations model in order to understand and forecast the simultaneous behaviour of the demand and supply of a commodity in the market.

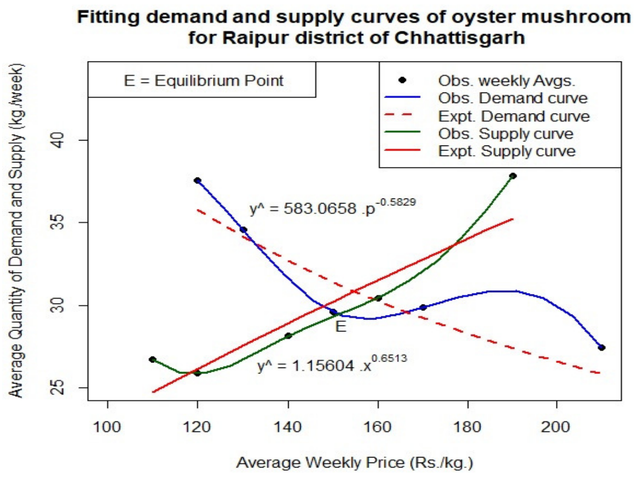

Fig. 1: Demand and Supply curves of oyster mushroom (*Pleurotus* spp.) for Raipur district of Chhattisgarh

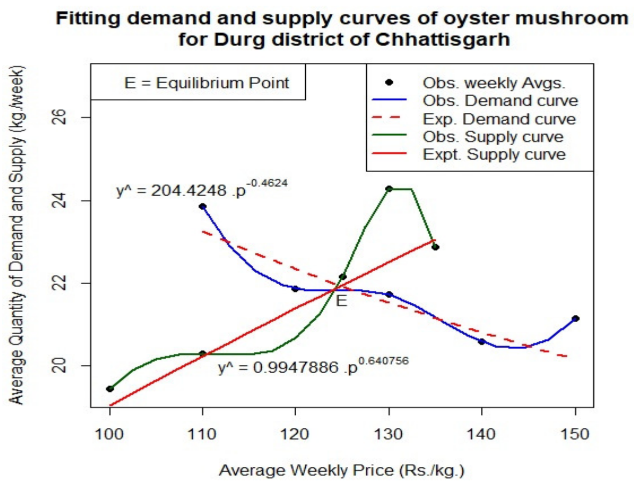

Fig. 2: Demand and Supply curves of oyster mushroom (*Pleurotus* spp.) for Durg district

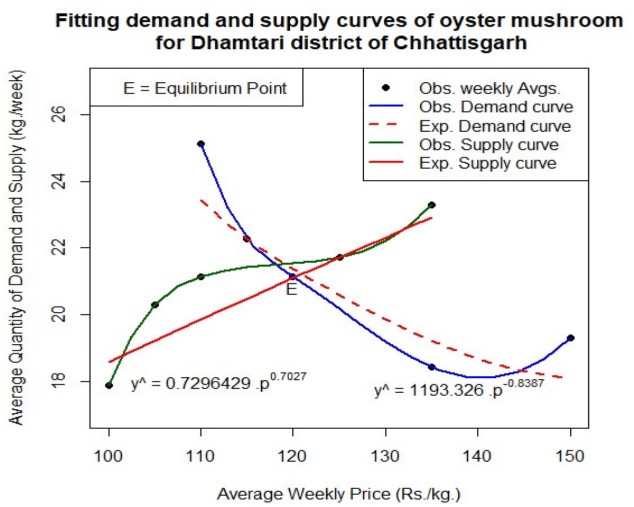

Fig. 3 : Demand and Supply curves of oyster mushroom (*Pleurotus* spp.) for Dhamtari district

Following are the conclusions on the basis of Figures:

(a) The Fig.01 indicates the equilibrium point (E) of demand and supply of oyster mushroom (*Pleurotus* spp.) in the Raipur market at the average weekly demanded of quantity is 29.5 kg/week for the average weekly price Rs. 152 per kg.

(b) The Fig.02 indicates the equilibrium point (E) of demand and supply of oyster mushroom (*Pleurotus* spp.) in the Durg market at the average demand of 21.8 kg/week for the average weekly price Rs. 123.5 per kg.

(c) The Fig.03 indicates the equilibrium point (E) of demand and supply of oyster mushroom (*Pleurotus* spp.) in the Dhamtari market at the average demand of 21.55 kg/week for the average weekly price Rs. 118.5 per kg.

Conclusion

The public chose soybeans over oyster mushrooms (Pleurotus spp.), hence Model I (Equations 17 and 18) was determined to be the best of the three models generated in the study. On the other hand, it was discovered that Model II (Equations 19 and 20) was only suitable for customers who chose chicken over oyster mushrooms (Pleurotus spp.) and had more disposable income than the average person.

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