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Estimation of the demand-supply system of the Egyptian gray cement using 2SLS-PC method

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Abstract

In this study, a simultaneous model describing the supply and demand system for Egyptian gray cement during time period 2006 until 2018 was estimated using the 2SLS-PC method, and it can be used in predicting the state of the Egyptian cement market. Gray cement represents an important strategic commodity and a major factor in the renaissance of countries for its use in infrastructure and construction works. The study aimed to identify the factors affecting the gray cement market in Egypt.

Key words: Simultaneous equations model, two stage least squares (2SLS), principal components (PC), instrumental variables (IV), two stage least squares with principal components (2SLS-PC) and Theil's forecast accuracy coefficient (U).

1 Introduction:

The estimation of the majority of large simultaneous-equation models frequently suffers from a smaller sample than the number of predetermined variables so a meaningful first –stage regression isn't possible or when the number of observations is small or too small compared with the number of predetermined variables.

A variety of strategies have been proposed to deal with the huge model and limited sample size problems. This study uses one of these solutions namely, the two stage least squares with principal components (2SLSPC) in which a small number of important principal components of the predetermined variables are used as instrumental variables (IV).

Both the principal components and instrumental variables modify the usual two-stage least squares (2SLS) estimation by limiting the number of variables employed in the first stage regression. The estimator proposed by (2SLSPC) uses the components associated with the largest characteristic roots of the correlation matrix of predetermined variables in the equation being estimated as first stage regression (Kloek & Mennes, 1960).

Gray cement is an important strategic commodity and a key factor in the renaissance of countries for use in infrastructure and construction works. The aims of studying the supply and demand of Egyptian gray cement to identify the factors that affect it. 2SLS-PC estimation method was applied to a simultaneous model describing the demand and supply for Egyptian cement.

2 Problem of research

The most of large simultaneous-equation models estimation frequently suffers of a smaller sample than the number of predetermined variables so that a meaningful first –stage regression isn't possible or when the number of observations is small or too small compared with the number of predetermined variables. This study deals with practical solution of the above mentioned difficult namely, (2SLSPC) method by means of the use of a limited number of principal components of predetermined variables are used as IV. The estimation method (2SLSPC) was applied to a simultaneous model describing the demand and supply for Egyptian cement.

3 Importance of the research:

1- Scientific importance:

Explanation and presentation one of the methods of dealing with the problem of estimating large simultaneous-equations models in number of predetermined variables with a small number of observations.

2- Practical importance:

Estimation of a simultaneous model that describes the supply and demand system for Egyptian gray cement and can be used in forecasting the state of the Egyptian cement market.

It is known that gray cement is the backbone of the construction activity. So, Egyptian gray cement industry is of immense strategic and economic importance to the Egyptian economy. Hence the Egyptian government has therefore paid considerable attention to the gray cement industry in order to satisfy the growing local demand for that good.

The scope of application in this study is to provide the supply and demand model of the Egyptian gray cement industry, studying the interrelationships among variables affecting the supply and demand of gray cement.

4 Objective of the research:

1- Presentation and using a 2SLSPC method for dealing with the problem of large simultaneous-equations model estimation with few observations.

2- Applying the 2SLSPC estimation method to a simultaneous model describing the demand and supply for Egyptian cement.

5 Hypotheses of research:

1- There are positive relationships between the quantity demanded for Egyptian gray cement and each of, the population in the midyear, the level of income, the lagged values of quantity demanded and there is positive general trend.
2- There is a negative relationship between quantity demanded for Egyptian gray cement and price of gray cement, the lagged values of price building iron and the lagged values of the price building materials.

3- There are positive relationships between the quantity supplied for Egyptian gray cement and each of the price of gray cement, the wages paid to laborers in the industry, the industrial expenditures, gross fixed capital formation and the lagged values of quantity supplied.

There is negative relationship between the quantity supplied for Egyptian gray cement and the industrial expenditures.

6 Limits of study:

1- This study is concerned with studying the Egyptian gray cement market during the time period from 2006 until 2018.

7 Two stage least squares estimation (TSLS)

The 2SLS estimator's algebra is more complicated than the IV estimator's. The general form,

$$\hat{\beta}^{IV} = (z' x)^{-1} z' y \qquad (7.1)$$

It is simple to demonstrate that this expression can be written as

$$\hat{\beta}^{IV} = (\hat{x}' \hat{x})^{-1} \hat{x}' y,$$

The explanatory variables are predicted rather than actual values in OLS (for the exogenous variables in x, predicted and actual values overlap).

The same expression holds for 2SLS:

$$\hat{\beta}^{2SLS} = (\hat{x}' \hat{x})^{-1} \hat{x}' y \qquad (7.2)$$

However, because the model is over-identified, there is no 2SLS corresponding expression (7.1). To see what the 2SLS estimator looks like when written in terms of the raw data vectors z and x, notice first that

$$\hat{x} = z\,(z'\,z)^{-1}\,z'x$$

(This is simply utilizing the OLS form in the first stage for the M dependent variables and the K explanatory variables in the second stage). When put this into (7.2):

$$\hat{\beta}^{2SLS} = (\,x'\,z\,(\,z'\,z)^{-1}\,z'z\,(\,z'\,z)^{-1}\,z'x)^{-1}\,x'\,z\,(\,z'\,z)^{-1}\,z'y$$

$$\hat{\beta}^{2SLS} = = (\,x'\,z\,(\,z'\,z)^{-1}\,z'x\,)^{-1}\,x'\,z\,(\,z'\,z)^{-1}\,z'y$$

The following is a frequent way of expressing this:

$\hat{\beta}^{2SLS} = (x' \, p_z \, x)^{-1} \, x' p_z \, y$

Where p_z = z $(z'$ z $)^{-1} z'$is known as the projection matrix.

8.1 Two stage least square with principal components method (TSLSPC):

If the predetermined variables of a model are highly correlated, their variation can be almost fully approximated by using a few of the first principal components. Also, when formulating TSLS instrumental variables, attempts are made to explain the variation in the endogenous variables by means of variance in the predetermined variables, whereas no attention is paid to the corresponding parameters themselves. According1y, replacing the predetermined variables is fair in the first stage of the TSLS method by a few of their first principa1 components when the number of observations is small or too small compared with the number of predetermined variables.

Principal components are normalized (the sum of squares of the coefficients concerned = 1) 1inear combinations of the variables to be examined. They are mutua11y orthogona1 and formed in order so that the variance of each principa1 component wi11 be maximized on the condition that the preceding 1inear combinations are given (Hirvonen, 1975). It is then assumed that the variables are either expressed as deviations from the mean or standardized (mean = 0, variance =1).

There are as many principal components as there are linearly independent variables in the original set of variables. Moreover, the matrix of all the principal components is an orthogonal transformation of the matrix of original observations, which means that the generalized variance and the sum of the variances of the principal components are respectively equal to the genera1ized variance and the total of the variances of the variables in question. Accordingly, the first principa1 component captures the greatest possible share of the variation in the original variables, while the second principal component, which is uncorrelated with the first, captures the largest possible share of the remaining variation and so on.

8.2 TSLSPC estimation

A linear structural relation which is part of a system of simultaneous equation can be written as:

y = Y γ + $X_l \, \beta$ + u (8.1)

where:

y: is a column vector of T observations and the jointly dependent variables.

Y: is a $T \times m$ matrix of observations on m explanatory jointly dependent variables.

X_1: is a T×l matrix of observation on 1 predetermined variable.

β and γ :are parameter vectors to be estimated.

U: is a column vector of disturbances.

The system as a whole is supposed to contain $L \geq l$ predetermined variables, the observations on which can be arranged in a $T \times L$ matrix x. so we can write:

$$X = [x_1 \quad x_2] \tag{8.2}$$

X_2 being the T x(L-l) matrix of observations on those predetermined variables which occur in the system but are excluded from (9.1) It is well known that it is impossible to estimate the parameters of (9.1) consistently unless the equation is identifiable, which requires:

$$L \geq m+1 \tag{8.3}$$

The method of (2SLS) applied to (8.1) implies estimation of γ, β according to

$$\begin{bmatrix} c \\ b \end{bmatrix} = \begin{bmatrix} Y'Y - V'V & Y'X_1 \\ X_1{}'Y & X_1{}'X_1 \end{bmatrix}^{-1} \begin{bmatrix} (Y-V)' \\ X_1{}' \end{bmatrix} Y \tag{8.4}$$

where V is the T x m matrix of least – squares estimated disturbances:

$$V = Y - X\,(X'\,X)^{-1}\,X'\,Y \tag{8.5}$$

If we want to improve these estimates by replacing X_2 by K principal components to be used as instrumental variables, the observations on which are arranged in a T× K matrix F.

This implies that we use an estimator C_1 , b_1 which is identical with (8.4) except that V is replaced by:

$$V_1 = Y - Z\,(Z'\,Z)^{-1}\,Z'Y \tag{8.6}$$

Where

$$Z = [X_1 \quad F] \tag{8.7}$$

The estimator can also be written as:

$$\begin{bmatrix} c_1 \\ b_1 \end{bmatrix} = \begin{bmatrix} Y'Z(Z'Z)^{-1}Z'Y & Y'X_1 \\ X_1{}'Y & X_1{}'X_1 \end{bmatrix}^{-1} \begin{bmatrix} Y'Z(Z'Z)^{-1} & Z' \\ X_1{}' & \end{bmatrix} Y \qquad (8.8)$$

This implies for the sampling error:

$$e = \begin{bmatrix} c_1 \\ b_1 \end{bmatrix} - \begin{bmatrix} \gamma \\ \beta \end{bmatrix}$$

$$= \begin{bmatrix} Y'Z(Z'Z)^{-1} & Y'X_1 \\ X_1{}'Y & X_1{}'X_1 \end{bmatrix}^{-1} \begin{bmatrix} Y'Z(Z'Z)^{-1} & Z' \\ X_1{}' & \end{bmatrix} u \qquad (8.9)$$

9 Specification of the model

Specification for the demand-supply system of the Egyptian gray cement which consists of two behavioral equations besides one identity describes the market-clearance or equilibrium:

Demand equation

$$\beta_{11}\ Qd_t + \beta_{12}\ Qs_t + \alpha_{11}\ P_t + \alpha_{12}\ POP_t + \alpha_{13}\ WAE_t + \alpha_{14}\ Lag\_R_t + \alpha_{15}\ Lag\_BS + \alpha_{16}\ Lag\_Qd + \alpha_{17}\ T_t + \alpha_{18}\ F_t + \alpha_{19}\ L_t + \alpha_{1,10}\ E_t + \alpha_{1,11}\ Lag\_Qs + \alpha_{1,12}\ D_t = U_{1t} \qquad (9.1)$$

Supply equation

$$\beta_{2\,1}\ Qd_t + \beta_{2\,2}\ Qs_t + \alpha_{2\,1}\ P_t + \alpha_{2\,2}\ POP_t + \alpha_{2\,3}\ WAE_t + \alpha_{2\,4} Lag\_R_t + \alpha_{2\,5}\ Lag\_BS + \alpha_{2\,6}\ Lag\_Qd + \alpha_{2\,7}\ T_t + \alpha_{2\,8}\ F_t + \alpha_{2\,9}\ L_t + \alpha_{2,10}\ E_t + \alpha_{2,11}\ Lag\_Qs + \alpha_{2,12}\ D_t = U_{2t} \qquad (9.2)$$

Equilibrium equation

$$Qd_t = Qs_t \qquad (9.3)$$

Where

Qd_t= Quantity demanded of the gray cement into thousand tons.

Qs_t= Quantity supplied of the gray cement into thousand tons.

P_t = The price index of the gray cement into hundred Egyptian pounds (2008 = 100).

POP_t = Population in the midyear in millions,

WAE_t = The level of income into thousand Egyptian pounds.

Lag_R_t = The lagged values of building iron price index thousand pounds (2008 = 100).

Lag_CS = The lagged values of building materials price index hundred Egyptian pounds (2008 = 100).

Lag_Qd = The lagged values of quantity demanded into thousand tons.

T_t= The time.

F_t= Gross fixed capital formation of the industry into million Egyptian pounds deflated to 2008 prices.

L_t = Wages paid to laborers in the industry into million Egyptian pounds.

E_t= the industrial expenditures into million Egyptian pounds deflated 2008 prices.

Lag_Qs = The lagged values of quantity supplied.

Besides a dummy variable D_t always equals unity to take care of the intercept.

10 Principal components analysis:

For the extraction of the PC associated with the predetermined variables excluded from the particular equation of the system, the simple summation method was applied.

10.1 The principal component used for demand equation:

A- The first component Z_{11} was:

Z_{11}= (-0.788) L_t + (-0.859) F_t+ (-0.903) E_t+ (-0.807) Lag_Qs

B- The second component Z_{21} was:

Z_{21}= (0.574) L_t + (-0.247) F_t+ (-0.109) E_t+ (0.509) Lag_Qs

10.2 The principal components used for supply equation:

A- The first component Z_{12} was:

Z_{12}= (0.986) POP_t + (0.967) WAE_t+ (0.805) Lag_R_t+ (0.968) Lag_CS + (0.778) Lag_Qd + (0.989) T_t

B- The second component Z_{22} was:

Z_{22}= (-0.059) POP_t + (-0.128) WAE_t+ (-0.304) Lag_R_t+ (-0.078) Lag_CS + (0.597) Lag_Qd + (0.038) T_t

11.1 Estimation for demand equation using 2SLS-PC method

Replacing predetermined variables L_t, F_t, E_t and Lag_Qs by the corresponding extracted two principal components (Z_{11},Z_{21}) and applying the method of 2SLS yields the following estimates:

$\widehat{Qd}_t$= 426 – 0.089 P_t– 4.715 POP_t- 0.60 WAE_t + 0.403 Lag_CS –

P-value (t): (0.056) (0.038) (0.148) (0.08)

0.276Lag_R_t – 1.418 Lag_Qd + 17.199 T_t

(0.019) (0.051) (0.008)

R^2= 0.924 F = 0.015

Run test of randomness (A) = 10

The tabulated values where:

n_1= 7 n_2 = 6 α = 0.05

Lower = 3 upper = 12

Elasticities of the explanatory variables with respect to the dependent variables:

η_p = -1.155 η_{pop}= -8.634

η_{WAE} = -0.399 η_{Lag_CS} = 0.558

η_{Lag_R} = -0.280 η_{Lag_Qd} = -1.393

Evaluation of demand equation

1- The positive relationship between quantity demanded and each of the lagged values of price building materials and the number of years this is consistent with hypotheses of study. The negative relationship between quantity demanded and the price of gray cement is consistent with the hypotheses of the study. The negative relationship between quantity demanded and each of the population in midyear, the level of income, the lagged values of iron price and the lagged values of quantity demanded isn't consistent with hypotheses of the study.

2- The determination coefficient (R^2) value is nearly 92% indicates to the explanatory variables succeed in explaining 92% of the changes in the quantity demanded and the other remaining value 8% return to the error term.

3- The results of t-test were showed significant all variables which p-value < 0.10 except one variable (WAE).

4- The result of F-test was showed the relationship is significant (p-value< 0.05, < 0.10).

5- To detected the presence of autocorrelation according to run test of randomness the numbers of runs (A) lie inside the borders of lower and upper values. We accept the null hypothesis the recursive of residuals is random (No-autocorrelation).

6- To detect to which the assumption of homoscedasticty of errors in the demand equation, spearman's correlation coefficients was tested between each explanatory variable separately and the residuals of the demand equation estimated using the t-test, and the results were as follows:

Table (1) Spearman's correlation coefficient of demand equation

variables	P_t	POP_t	WAE_t	Lag_CS	Lag_R_t	Lag_Qd	T_t
r_s	-0.006	-0.033	0.058	-0.033	-0.06	-0.187	-0.033
t_c	-0.020	-0.114	0.200	-0.114	-0.207	-0.658	-0.114

Source: preparation the researcher using SPSS

Where $t_{(11\ ,0.025)}$= 2.201

- According to spearman's correlation coefficients between $|\hat{u}_1|$ and each explanatory variable $|t_c| < t_{(11\ ,0.025)}$, thus, there is no evidence of a relationship between each explanatory variable and the absolute values of the residuals, which might suggest that there is no heteroscedasticity.

7- To detect the normality distribution assumption by use Kolmogorov-Smirnov (K-S) test the results were as follows:

Table (2) Kolmogorov-Smirnov of demand equation

Eq.1	Error for Qd
N	13
Mean	0.000
Std.D	1.350
Test statistic	0.215
Asymp.Sig	0.104

Source: preparation the researcher using SPSS

Where the tabulated value $D_{(13\ ,0.05)}$ = 0.361 $>$ D_c = 0.215 according (K-S) test, we accept the null hypothesis the errors are distributed normality.

8- The results of comparing the values of the simple correlation coefficients between each pair of the equation variables with the value of multiple correlation coefficients for the equation, achieving Klien's rule that no harmful from multicollinearity.

$$R_{y.x_1x_2.....,x_l}(0.961) \geq r_{x_ix_j}$$

Where:

$r_{x_ix_j}$: The simple correlation between any two explanatory variables.

$R_{y.x_1x_2.....,x_l}$: The multiple correlation of the relationship.

9- Theil's Forecast Accuracy coefficient to detect the prediction ability of the model as following:

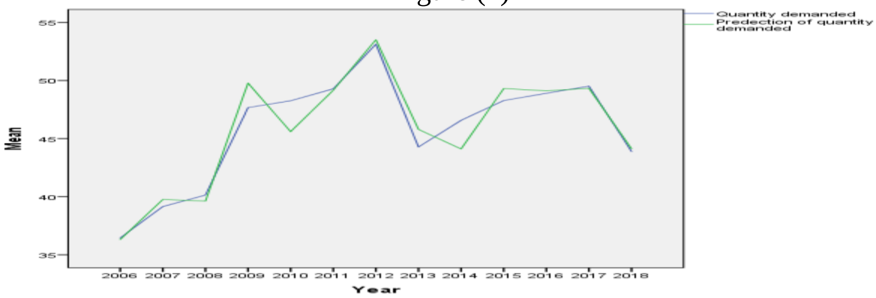
$\sum \hat{e}^2$ = 21.874 $\qquad$ $\sum(Qd_t - Qd_{t-1})^2$= 207.159

$$\text{U} = \sqrt{\frac{21.874}{207.159}} = 0.324$$

According to Theil test, the demand equation ability of prediction is perfect (good).

Figure (1) shows the actual and predicted curve of demand equation.

Figure (1)



Source: preparation the researcher using SPSS

10- It is clear from the calculated values of the elasticity of demand that the demand for cement is elastic with respect to price, population and previous demanded quantities.

11.2 Estimation for supply equation using 2SLSPC method

$\widehat{Qs}_t$= -6.108 + 0.049 P_t+ 0.021 L_t- 0.856 E_t + 0.263F_t

P-value (t): (0.231) (0.021) (0.424) (0.866)

+ 0.415 Lag_Qs

(0.068)

R^2= 0.835 F = 0.012

Run test of randomness (A) = 8

The tabulated values where:

n_1= 7 n_2 = 6 α = 0.05

Lower = 3 upper = 12

Elasticities of the explanatory variables with respect to the dependent variables:

η_p = 0.635 η_L = 0.168

η_E = -0.121 η_F = 0.049

η_{Lag_Qs} = 0.405

Evaluation of supply equation

1- The positive relationship between the quantity supplied and each of price of gray cement, wages paid of laborers, gross fixed capital formation and the lagged values of quantity supplied is consistent with hypotheses of the study. The negative relationship between the quantity supplied and the industrial expenditures is consistent with the hypotheses of the study.

2- The determination coefficient (R^2) value is nearly 84% indicate to the explanatory variables succeed in explaining 84% of the changes in the dependent variable and the other remaining value 16% return to the error term.

3- The results of t-test were showed significant variables which L_t at %5 (p-value $<$ 0.05) and Lag_Qs at %10 h (p-value $<$ 0.10).

4- The result of F-test was showed the relationship is significant p-value$<$ 0.05.

5- To detected the presence of autocorrelation according to run test of randomness the numbers of runs (A) lie inside the borders of lower and upper values. We accept the null hypothesis the recursive of residuals is random (No-autocorrelation).

6- To detect to which the assumption of homoscedasticty of errors in the demand equation, spearman's correlation coefficients were tested between each explanatory variable separately and the residuals of the demand equation estimated using the t-test, and the results were as follows:

Table (3) Spearman's correlation coefficient of supply equation

variables	P_t	L_t	E_t	F_t	Lag_Qs
r_s	-0.193	-0.110	-0.110	-0.033	0.121
t_c	-0.680	-0.383	-0.383	-0.114	0.422

Source: preparation the researcher using SPSS

Where $t_{(11\,,0.025)}$= 2.201

- According to spearman's correlation coefficients between $|\hat{u}_1|$ and each explanatory variable $|t_c| < t_{(11\,,0.025)}$, as results, there is no evidence of a relationship between the absolute values of the residuals and each explanatory variable, which might suggest that there is no heteroscedasticity.

7- To detect the normality distribution assumption by use Kolmogorov-Smirnov (K-S) test the results were as follows:

Table (4) Kolmogorov-Smirnov of supply equation

Eq.1	Error for Qd
N	13
Mean	0.000
Std.D	2
Test statistic	0.112
Asymp.Sig	0.200

Source: preparation the researcher using SPSS

Where the tabulated value $D_{(13\ ,0.05)}$ = 0.361> D_c = 0.112 according (K-S) test, we accept the null hypothesis the errors are distributed normality.

8-

$$R_{y.x_1x_2.....,x_l} \geq r_{x_ix_j}$$

Where:

$r_{x_ix_j}$: The simple correlation between any two explanatory variables.

$R_{y.x_1x_2.....,x_l}$: The multiple correlation of the relationship.

The results of comparing the value of multiple correlation coefficient for the equation(0.914) ≥ the values of the simple correlation coefficients between each pairs of the equation variables(table of correlation page 88) that's achieving Klien's rule no harmful from multicollinearity.

9-Theil's Forecast Accuracy coefficient to detect the prediction ability of the model as following:

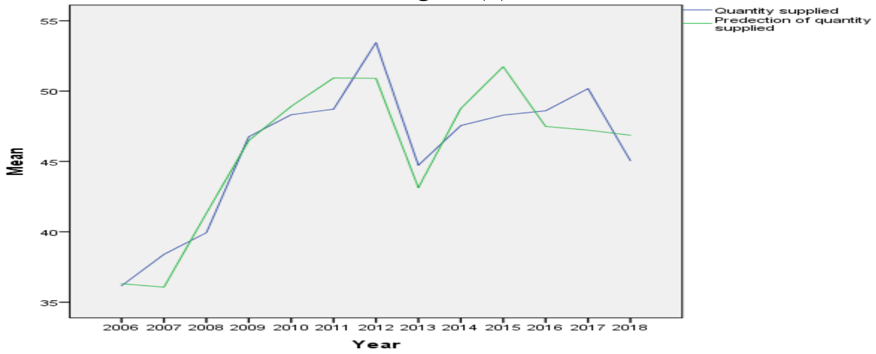
$\sum \hat{e}^2$ = 48.231 $\sum(Qs_t - Qs_{t-1})^2$= 209.511

$$U = \sqrt{\frac{48.231}{209.511}} = 0.479$$

According to Theil test, the supply equation ability of prediction is perfect (good).

Figure (2) shows the actual and predicted curve of supply equation.

Figure (2)



Source: preparation the researcher using SPSS

10- It is clear from the calculated values of the elasticity of supply that the supply of cement is inelastic with respect to both labor wages and the previous supplied quantities.

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