

APPLICATION OF SIMULTANEOUS EQUATIONS MODEL TO ESTIMATE PARTICLEBOARD DEMAND AND SUPPLY

Ajang Tajdini,* Amir Tavakkoli, Ahmad Jahan Latibari, Mehran Roohnia, and Seyed Ali Haji Mirza Tayeb

Dynamic supply and demand equations for particleboard using a three-stage squares simulation (3SLS) were estimated. Empirical data included annual observations over the period of 1976 to 2006. The stationary character of the data was checked by applying the Augmented Dickey-Fuller (ADF) Test. The results revealed that in the demand function, variables such as particleboard price, the gross national product (GNP) in the previous year (lagged quantity), and the MDF price were significant at 0.05%. In the supply function, variables such as the price of medium density fiberboard (MDF), demand for particleboard in the previous year, the product/raw material price ratio in the previous year, and particleboard imports in the previous year were shown to be significant at 0.05%. Also price, income, and cross elasticities of demand for particleboard were calculated as -0.65, 0.32, and 1.63, respectively, indicating that this commodity is a necessary and normal good and MDF is a substitute for it.

Keywords: Elasticities; Simultaneous; Particleboard; Supply; Demand

*Contact information: Department of Wood Science and Technology, Islamic Azad University, Karaj branch; * Corresponding author: ajang.tajdini@kiaiu.ac.ir*

INTRODUCTION

Particleboard is the major raw material used for wooden furniture as well as for the construction industries in Iran and the Middle East. The establishment of the first particleboard manufacturing facility in this region took place more than 50 years ago. During the subsequent period, the industry, due to its use of low-cost raw materials such as forest and agriculture residues, as well as wastes from other wood processing plants, has become one of the most important sources of wood-based panels (Jahanshahi 2009). It is reported that in Iran, particleboard production has increased from 383,000 m³ in 1997 to 718,000 m³ in 2007, and the consumption also rose from about 370,000 m³ in 1997 to more than 697,000 m³ in 2007 (Azizi et al. 2007). It is also predicted that the consumption of particleboard in Iran will reach 900,000 m³ in 2012. However, as of this year, Iran is only able to produce 800,000 m³, and so the rest has to be supplied via imports. The available data also show that in 2008 alone over 530,000 tons of particleboard at a cost of about 13.5 million dollars was imported (IWIEA 2008). A similar situation exists in the rest of the Middle East.

A wealth of literature reporting on the studies of different forest products supply and demand and to estimate the price and income elasticities have become available since the 1990s. These studies cover the work of Prestemon and Buongiorno (1993), Brooks *et*

al. (1995), Chas-Amill and Buongiorno (2000), Kangs and Buadin (2003), Hemmasi, *et al.* (2006), and Wear and Lee (1993), but only few have focused on simultaneous estimation of supply and demand models. Toppinen (1998) applied a maximum likelihood approach, following Johansen and Juselius (1990, 1992) to estimate a long-run demand and supply model for the Finnish saw log market with log-transformed monthly data.

The demand and supply relations can be estimated using a traditional 2SLS method. Even though this method was initially developed based on an assumption that all data are stationary, Hsiao (1997a,b, 2005), Golinell and Roveelli (2005), and Shrestha and Tan (2005) have extended the application of the structural dynamic simultaneous equations model on non-stationary variables. Luo (2003) estimated U.S. linerboard supply and demand functions using a simultaneous equations system and monthly data from Jan. 1982 to Dec. 1999, applying a 2SLS procedure. The results indicated that linerboard is price and income inelastic, and plastic packaging should be considered to be a substitute material. Tavakkoli (2009), applying a simultaneous equations system, investigated the corrugated board supply and demand situation in Iran with the aid of a 3SLS procedure and annual time series data from 1981 to 2007. The results showed that in the demand function, variables such as the GNP in the previous year, population, consumer price index (CPI), and added value of this industrial section and in the supply function, variables such as production, consumption, and import quantities, as well as production cost of particleboard in the previous year, and inflation rate are statistically significant. The use of a production function approach, which can be used to develop either cost or profit functions, is another procedure to derive the output demand and input supply functions through the application of Hotellings Lemma to the profit or cost function as a dual of the production function. Nagubadi and Zhang (2006) used an econometric approach to study the production structure and input substitution in sawmill and wood-preservation industry in Canada from 1958 to 2003. Unlike the index number approach, the econometric approach (trans-log function) enables researchers to estimate the parameters of interest, that is, elasticities of factor substitution, elasticities of factor demand, and economics of scales. Li (2009) for masters of science thesis used a trans-log cost function to specify the production structures of the softwood lumber industry in three U.S. regions (the West Coast, the Inland, and the South), and four Canadian regions (Ontario, the British Columbia Coast, the British Columbia Interior, and Quebec), from 1988 to 2005. First, two separate production models were specified and analyzed; one was a “U.S. model” for the U.S. regions, and the other was a “Canada model” for the Canadian regions. Second, all seven regions were included in one production model, a “U.S.-Canada model”.

Unfortunately, the available data in underdeveloped regions such as Middle East is limited, and in order to be able to estimate the demand and supply equations, we need to derive an appropriate model. A properly specified demand and supply econometric model that estimates total consumption and production can be helpful to describe the interaction of consumers and particleboard industries. Such a model parameterizes the effects of factors affecting the balance between quantities consumed and produced, as well as the price and income of particleboard production. The model can be used to estimate the effects of explanatory variables on market conditions.

The term “stationary” is used to define a condition that must be assessed for time series analysis. A time series is said to be stationary if the mean and auto-covariance of the series do not depend on time. This means that the series does not have an upward or downward trend over time. Standard estimation procedures cannot be applied to a model that contains a non-stationary variable (Hamilton 1994). Also, a non-stationary time series has a possibility of spurious regression. This means that in regression a time series variable on another time series variable(s), one often obtains a very high R^2 (in excess of 0.9) even though there is no meaningful relationship between the two variables. Sometimes we expect no relationship between two variables, yet a regression of one on the other variable often shows a significant relationship. This situation exemplifies the problem of spurious, or nonsense regression (Gujarati 2004). Therefore, we should check whether a series is stationary or not before using it in a model. The formal method of testing the stationary character of a series is the unit root test.

The objectives of this study were to estimate a system of dynamic econometric model using annual data for the period of 1976 to 2006 and a systematic approach of iterative 3-stage least squares (I3SLS). The reason to use simultaneous equations is the existence of reciprocal relations between economic variables in our research, such as the volume of supply and demand. Furthermore, in this system due to the presence of the correlation between residual terms in structural equations of supply and demand, the 3SLS method was selected. This method is different from 2SLS method. The three-stage least-squares method generalizes the two-stage least-squares method to take account of the correlations between equations in the same way that SUR generalizes OLS. In fact, the difference between 2SLS and 3SLS is in correlation between the error terms across the equation. The strength and perfection of this method among the other systemic approaches with Full Information Maximum Likelihood (FIML) is another reason. However, both methods are consistent and efficient (Abrishami 1999). Price elasticities of particleboard supply and demand can be derived from the estimated model. This research emphasizes the implication of including lagged dependent variables in market modeling.

EXPERIMENTAL

Model Specification

In order to enrich and strengthen our understanding of particleboard industry as well as to obtain consistent estimates of both the supply and demand in Iran as a representative country in the Middle East, we incorporated some degree of oligopoly in our research, because there are more than 15 factories that are producing this product in Iran but only four of them are large-scale mills; therefore these companies can create a kind of monopoly in the market. Meanwhile, demand and supply of particleboard in Iran as endogenous variables were considered as a function of several explanatory variables. The procedure used in selecting the variables was based on the theoretical background of demand and supply theories and influential macroeconomic data. Particleboard supply and demand were estimated by applying simultaneous equations according to the 3SLS procedure and the time series data for the period of 1976 to 2006. The functional form for

supply and demand equations was in the form of log-log equations, which allows direct interpretation of estimated coefficients in terms of elasticity (Gujarati 2004). This model includes two logarithmic equations for supply and demand, and each for particleboard is defined as follows:

Demand Equation

The demand for particleboard as an endogenous variable is a function of variation in influential variables (exogenous variables) including macroeconomic data and industrial indices such as added value for furniture and construction sectors. In this study, we assume a demand equation as follows:

$$\begin{aligned} \ln(X_t^d) = & C_1 + C_2 \ln(PX_t) + C_3 \ln(GNP_{t-1}) + C_4 \ln(CPI_t) + C_5 \ln(J_t) \\ & + C_6 \ln(PY_t) + C_7 \ln(FA_t) + C_8 \ln(CA_t) + U_t^d \end{aligned} \quad (1)$$

In this equation X_t^d is the particleboard demand of Iran, PX_t is the domestic particleboard price as the most important effective factor, GNP_{t-1} is the gross national product of Iran in the previous year as a index of consumers income, CPI_t is the consumer price index as a index of consumer goods and services price, J_t is the population of Iran, and PY_t is the domestic MDF¹ price. In this paper we assumed that MDF is a complementary commodity item for particleboard, so on the basis the demand theory the price of this product affects the demand for particleboard. FA_t is the added value for the furniture sector of Iran. CA_t is the added value for the construction sector of Iran due to the use of particleboard mainly as a raw material in construction and furniture industries. So demand for this product is a function of development of mentioned industries in the country, and U_t^d is a demand residual term.

According to the above function, it is expected that the signs of the coefficients of the variables will be as follows:

$$C_2 < 0, C_3 > 0, C_4 < 0, C_5 > 0, C_6 > 0, C_7 > 0$$

The coefficients of PX_t and CPI_t are expected to be negative because there is a adverse relationship between price and demand for a product. The coefficient of GNP_{t-1} is expected to be positive because demand of particleboard is non-decreasing in consumers income. The coefficient of MDF price must be positive, because this product is a substitute good for particleboard. The coefficients of added values of the construction and furniture industries are expected to be positive because the product is a raw material for these.

Supply Equation

The derived log-transformed particleboard supply as an endogenous variable can be expressed as a function of influential variables (exogenous variables) based on supply theory. Similar to the demand equation, the particleboard supply equation includes lagged variables to represent delayed responses to market signals,

¹ MDF = Medium Density Fiber, which is one of the most used products in wood-based panels.

$$\begin{aligned} \ln(X_t^s) = & C_8 + C_9 \ln(PY_t) + C_{10} \ln(X_{t-1}^s) + C_{11} \ln(PX_t) + C_{12} \ln(IM_{t-1}) \\ & + C_{13} \ln(X_{t-1}^d) + C_{14} \ln(PX_{t-1}/PS_{t-1}) + U_t^s \end{aligned} \quad (2)$$

where X_t^s is the particleboard supply of Iran, PY_t is the domestic MDF price as a substitute good for particleboard; therefore the demanded quantity of this product has an effect on particleboard supply, X_{t-1}^s is the supply quantity in the previous period, PX_t is the domestic particleboard price, noting that there is a positive relationship between this factor and supplied particleboard, IM_{t-1} is the quantity imported of particleboard to Iran in the previous period, X_{t-1}^d is demand for particleboard in the previous period, PX_{t-1}/PS_{t-1} is the product price in the previous period - the raw material price in the previous period as a ratio of particleboard. The lagged dependent variables were included in the particleboard supply model because according to dynamic equilibrium of supply and demand, any changes in supply of particleboard will occur after that the first lag in these variables, and U_t^d is the supply residual terms. It is expected that the signs of coefficients of the variables will be as follows:

$$C_9 > 0, C_{10} < 0, C_{11} > 0, C_{12} < 0, C_{13} > 0, C_{14} > 0$$

The coefficient of MDF price is expected to be positive because the supply of particleboard does not decrease as a result of the substitute price. The coefficients of supply and import lagged exogenous variables are expected to be negative because these have adverse effect on supplied particleboard. The coefficient of the first lagged variable of demanded particleboard is expected to be positive because particleboard manufacturers are ready to supply when the demand is high. The coefficient of the PX_{t-1}/PS_{t-1} variable is expected to be positive because supply of particleboard is non-decreasing in its own price or adverse input price.

The Data and Information

Annual data from 1976 to 2006 were used for model estimation. The consumption data is evaluated based on an apparent consumption method (*consumption = domestic production + import - export*). The data for the price of product and MDF as substitute good, as well as forest residues as raw material were obtained from the Ministry of Industries and Mines database and the financial information for accepted enterprises in Tehran Stock Exchange Corporation such as Neopane 22 Bahman. The quantity of particleboard produced (m^3) and population (x1000 persons) was received from the Statistical Center of Iran, and the import and export quantities were extracted from *Iran Foreign Trade Annual Book*. All data related to Consumer Price Index (CPI), added value of furniture sector, added value of construction sector, and Gross National Product (in billion rails) were collected from the Central Bank of Iran, and the values were deflated based on the year 1997.

To find out if any series is stationary, the regression was run on

$$y_t = c + \sum_{i=1}^n \alpha_i y_{t-i} + u_t \quad (3)$$

where y_t is the vector of Iranian demand and supply quantities of particleboard. Also, it was found if the absolute value of any α_i was statistically equal to one on the basis of the t statistic. The estimated coefficient was divided by its standard error to compute the statistics, and the results were referred to the Dickey-Fuller table. If the absolute computed value exceeded the Dickey-Fuller absolute critical value, then the hypothesis that the given time series is non-stationary was rejected. If, on the other hand, it was less than the absolute critical value, the time series was found to be non-stationary. The tests was run with an intercept and a trend and intercept but not a trend. If the series was non-stationary, it was transformed by taking the first differences over 1 year. The above procedure was repeated until a stationary series was achieved (Kim *et al.* 2003).

Lags of exogenous and endogenous variables have impacts on particleboard supply and demand because response of dependent variables to changes in independent variables may take several time periods. However, these lagged variables are mainly correlated with current particleboard supply.

RESULTS AND DISCUSSION

The results of the unit root test indicate that even though all of the variables in the logarithmic form were non-stationary at the 5%, the first differentiation of their log-transformation will be stationary. Therefore the variables are designated as I(1) or integrated of order 1 and then introduced to the model. Before the estimation, the equations of the system were examined with respect to the identification problem, and by applying the order and rank conditions it was determined that all of them were in an over-identified condition. This means that in the given demand and supply model, the number of structural coefficients is less than the number of equations. In such situations in 2SLS and 3SLS methods, unlike ILS, which provides multiple estimates of parameters in the over identified equations, these provide only one estimate per parameter (Gujarati 2004). Then, we could estimate the coefficients, which are summarized in Table 1.

As observed in the demand function, the intercept (the average effects of all omitted variables from model on dependent variable) was estimated as -11.91, which is significant at the 5% level. Price elasticity of demand for particleboard was estimated at -0.65, which is significant, indicating that whenever the price of particleboard increases by 1%, the demand decreases partially by 0.65 percent. The minus sign on the coefficient is in accordance with an expectation that the demand is almost price-inelastic. The small magnitude of own-price elasticity is consistent with reports for other forest products. For instance, Chas-Amil and Buongiorno (2000) found that the demand for paper and paperboard was price-inelastic in the European Union, with price elasticities ranging from 0.13 to -0.30. The coefficient of Gross National Product in the previous year was estimated as 0.32, which is significant at 5%. The coefficient shows that a one percent increase in GNP in the previous year causes the current demand for particleboard to increase by 0.32%, and a positive sign of the coefficient was also expected. Also, the small income elasticity is in accordance with other studies. Luo (2003) in similar research on linerboard acknowledged that income elasticity for short-run are 0.17 to 0.25 and suggested that linerboard is a normal commodity. The coefficient of consumer price

index was not significant, which indicates that this variable has no effect on demand for particleboard.

Table 1. Demand and Supply 3SLS Coefficients Estimates

Variables	Coefficients	Standard Error	T Statistics
Demand Function			
LnX ^d _t : Dependent Variable			
Constant	-11.91*	1.98	-6.10
LnPX _t	-0.65*	0.26	-2.52
LnGNP _{t-1}	0.32*	0.14	2.21
LnCPI _t	-0.08	0.27	-0.29
LnJ _t	2.17*	0.19	11.26
LnPY _t	1.63*	0.58	2.78
LnFA _t	0.04	0.10	0.38
LnCA _t	-0.05	0.11	-0.48
R ² = 0.93			
Supply Function			
LnX ^s _t : Dependent Variable			
Constant	2.34*	0.61	3.83
LnPY _t	2.31*	0.64	3.58
LnX ^s _{t-1}	-0.18	0.12	-1.41
LnPX _t	-0.50	0.29	-1.70
LnIM _{t-1}	-0.03*	0.01	-3.80
LnX ^d _{t-1}	0.78*	0.06	12.90
Ln(PX _{t-1} /PS _{t-1})	0.40*	0.17	2.30
R ² = 0.94			

* indicates Statistical significant a 5% level.

The other important variable affecting demand for a given good is population. The results show that the coefficient of this variable is estimated as 2.17, which indicate that any one percent increase in population could increase particleboard demand by 2.17 percent. Cross price elasticity of demand for MDF as a substitute good for particleboard is estimated to be 1.63, which is significant at the 0.05% level. This enables us to express that any one percent increase in MDF price will increase the demand for particleboard by 1.63 percent. The substitute is highly significant. Luo (2003) found that plastic packaging is a substitute commodity for linerboard, but with cross-price elasticity being small, from 0.16 to 0.21. In the derived function, the coefficient of determination (R²) was calculated as 0.93, which indicates that explanatory variables are responsible for 93 percent of the variation of the dependent variable. This is the reason for the best fit of the demand function.

In the supply function, the intercept was estimated as 2.34, and it was statistically significant. The coefficient of MDF price variable was estimated as 2.31, which indicates that any one percent increase in price of this good as a substitute good will increase particleboard supply by 2.31 percent, and the positive sign of the coefficient is in

agreement with our expectations and it is based on supply theory. The particleboard supply coefficient with the first lagged quantity was not statistically significant, which shows that particleboard supply in the country during the previous year has no effect on particleboard supply in the following year. The coefficient of the first lagged quantity of import variable was estimated as -0.03, which indicates that any increase in imports of particleboard in the previous year will decrease the domestic production quantity by 0.03 percent. The minus sign of the coefficient is completely in accordance with our expectations, although the small value of the coefficient reveals that particleboard is fairly inelastic with respect to imports. The coefficient of demand quantity with the first lagged quantity was estimated as 0.78, which indicates that any one percent increase in particleboard demand in the previous year will increase the supply in the following year by 0.78 percent. The positive effect of the coefficient of the product price-raw material price ratio with the first lagged quantity was significant at the 5% level and shows that any rise in the current price of the product or lowering the current price of raw material will cause an increase in the supply of particleboard in the following year. An adverse relationship between raw material price and particleboard supply is consistent with the findings of Song et al. (2011), who realized that timber price has a negative effect on U.S softwood lumber volume. The coefficient of determination (R^2) was evaluated as 0.94, indicating that explanatory variables will respond to 94 percent of dependant variable (supply) variations.

CONCLUSIONS

The results of simultaneous estimation of particleboard supply and demand equations using the available annual data for the period of 1976 to 2006 and the 3SLS procedure revealed interesting findings. The strength of the applied system lies in its potential to handle the existence of interactions among variables and the robust results derived from the utilized data. A negative impact of demand price elasticity was found, in accordance with demand theory, which states that the demand for goods in any time period has an adverse relation with the price. Therefore, any increase in the price of particleboard will divert many of the consumers away from this commodity and shows their propensity to then use substitute goods such as MDF, plywood, etc. The results also indicated that particleboard is a normal commodity, and since its elasticity is less than one, it seems that any increase in the price of particleboard can lead to a considerable rise in total income for producers. The minimum values of elasticity calculated states that particleboard is almost price-inelastic, and this product is essential for its consumer in furniture and construction industries.

The positive effect of GNP in the previous year on the current demand indicates that in case the economic situation improves and consequently the consumer income rises, the demand for particleboard in the following year will rise, owing to the rise in utilization of furniture as luxurious consumer goods and the necessity for construction to meet the demand. The lack of influence of changes in the CPI indicates that any fluctuation in the price of consuming goods and services does not impose any influence on the demand for particleboard as well as its price, again indicating that the studied

product is an essential commodity. The correlation between population and demand indicates that any increase in population will cause higher consumption of all kinds of furniture and construction of new buildings directly. There is a positive relation between MDF price and particleboard demand, which indicates that MDF is absolutely a substitute good for the studied product. So any increase in MDF price leads to decrease in its demand and as a result causes a consumer tendency towards the use of particleboard.

The positive elasticity between MDF price and particleboard supply shows that MDF is a substitute good for particleboard. Therefore, any increase in the price of MDF will lead to an increase in demand for the studied product, and the consequence of this will be the increase in its supply by manufacturers in order to achieve higher profits and to take a higher share of the market. The absence of a significant effect of the supply in the previous year on the current supply indicates that in case of particleboard, the consumer demand is greater than the available supply (excess demand). Thus, to satisfy this need, extensive investment is needed in establishing new plants. The adverse impact of particleboard import in a previous year on the current supply indicates that any increase in import of the product will reduce its price in the domestic market and therefore, producers are likely to continue the trend of reducing price in the following year, which will decrease the supply of studied product. The increase in the current supply of particleboard due to increased demand in the previous year, proves that the manufacturers desire to achieve higher income and consequently more profit. The positive relation between product price versus raw material price ratio in the previous year with current supply of particleboard shows that any rise in the price of particleboard or reduction the price of wood as the most important raw material causes the manufacturers to think that the mentioned trend will continue in the following year, and therefore they will increase the supply. Also the positive and negative effects of all explanatory variables on the dependent variables equations (supply and demand quantities of particleboard) are in accordance with expectations and are based on theoretical principles (the theories of demand and supply). Our estimation is based on the data from one of the Middle East countries (Iran), but in principle such results are expected to apply not only to the Middle East but also to most fiber-deficient regions.

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