A SIMULTANEOUS EQUATION MODEL OF THE U. S. CARPET INDUSTRY

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Introduction

The carpet and rug industry of the United States grew at approximately 14% per year during the period from the late 1950's to the early 1970's, with the major portion of the growth attributable to tufted carpets and rugs. The latter constitute about 92% of the total market today, with woven carpets making up about 2.5 to 3%, needlepunch carpets accounting for about 4% and the remainder of the market consisting of knitted, braided and hooked fabrics.

The industry is predominately a tufted industry today. Value added by domestic carpet and rug manufacturers amounted to almost a billion dollars in 1973, and the dollar value of production at the mill level grew rapidly during the 1960's to exceed $3 billion in 1973, as compared to a total of less than one-fifth of that in 1960. The growth of the tufted sector ranked third among four digit SIC industries during the 1958-1969 period, based on DOC value-of-shipments data. This rate of growth was exceeded only by the semi-conductor and ammunition industry. Perhaps this outstanding growth was a contributing factor for the industry being unprepared for economic slump of 1970 and poorly prepared for the sharp downturn of 1974, but, whatever the reasons, a better information system is required for the industry and its suppliers.

In addition to basic information for decision-making at the firm level for carpet and associated firms, several governmental agencies and units could well benefit from a consistent, scientific tool for policy formation and for forecasts of sales and capacity. Such a tool, properly developed and utilized, could well assist in structuring the industry, and in so doing, provide insights into the industry that would not generally be available otherwise.

Reasons for the Study

There are multiple reasons that justify a study of this nature due to both the forecasting and the explanatory capabilities of such a model. From the forecasting aspect, a reason is that carpet manufacturers need information regarding future consumption and price levels of carpets at the time of evaluating investment alternatives. Typically, in the industry, firms note their present share of the market and then make use of long term industry forecasts as to revenue and yardage to decide on the capital appropriations to make under the assumption that they will maintain that share of the market. If they expect their share to change, they will adjust the appropriations accordingly. These "long term" forecasts, however, have typically been made with methods that are best suited for forecasting in the short term; methods such as exponential smoothing, trend and seasonal analysis are short term methods since they implicitly assume a stable and recurrent pattern of determination of the variables that exogenously have an effect on the sector or industry of interest, such as the carpet industry. For example, these short term methods would assume a stable and repeated pattern in the construction industry. If there is a change in the pattern of determination of the number of housing starts, perhaps due to a change in governmental policy with regards to subsidized housing construction, such methods would have no means of incorporating this change or of estimating what the quantitative effects of such a policy may be on the carpet industry's output.

Suppliers to the carpet industry, such as fiber producers and yarn manufacturers, would also benefit from the long-term forecasting capabilities of such a model, as they too have to make capital expenditure decisions, and in the case of the man-made fiber industry these decisions have to be made well in advance due to the capital intensiveness of the production process.

Government also has use for an econometric model of the industry; with the increased employment in carpet manufacture and with the additional consideration that a substantial portion of the industry's output is produced in one country, government needs the forecasts of this model in order to plan housing policies so as to provide an adequate spatial distribution of the labor force.

The explanatory aspects of the model are also of interest to the possible users; the model is set up in terms of structural relationships that are the demand and supply equations of carpets and of their inputs. Manufacturers of carpets are interested in the ceteris paribus effect of a change in price on the quantity demanded of carpeting of the kinds considered in this study. The same interest holds true for suppliers to the industry and in particular synthetic fiber manufacturers as carpet producers and their largest clients and the former are interested in estimating the expected change in fiber utilization due to a change in the unit price of fibers. A correctly specified model will allow for the

estimation of these price elasticities. An impact multiplier, which refers to the size of the change in an endogenous variable due to a small change in the value of an exogenous variable, is also of direct policy interest. In a simplified two equation model, for example

$$Y_1 = \beta_1 Y_2 + \alpha_1 x_1 + \mu_1$$

and

$$Y_1 = \beta_2 Y_2 + \alpha_2 x_2 + \mu_2$$

where Y_1 and Y_2 are endogenous, x_1 and x_2 are exogenous, μ_1 and μ_2 are random variables with zero expected value and finite variance, and β_1, β_2, α_1 and α_2 are parameters. Solving Y_1 and Y_2:

$$Y_1 = -\frac{\alpha_1\beta_2}{(\beta_1-\beta_2)}x_1 + \frac{\beta_1\alpha_2}{(\beta_1-\beta_2)}x_2 - \frac{\beta_2}{(\beta_1-\beta_2)}\mu_1 + \frac{\beta_1}{(\beta_1-\beta_2)}\mu_2$$

$$Y_2 = -\frac{\alpha_1}{(\beta_1-\beta_2)}x_1 + \frac{\alpha_1}{(\beta_1-\beta_2)}x_2 - \frac{1}{(\beta_1-\beta_2)}\mu_1 + \frac{1}{(\beta_1-\beta_2)}\mu_2$$

The impact multiplier on Y_1 of a change in x_1 is $-\alpha_1\beta_2/(\beta_1-\beta_2)$, while the impact of the same change on Y_2 is $\alpha_1/(\beta_2-\beta_1)$. In reference to Y_1, the short term multiplier refers to the size of the change in Y_1 due to a unit change in x_1, whereupon x_1 will return to its original value. The long term multiplier refers to the change in the level of Y_1 due to a permanent change in the level of x_1. For example, government may consider the implementation of quotas and/or tariffs of man-made fiber products. These tariffs and/or quotas will have an effect on the prices and availability of carpet yarn, which in turn will have an effect on prices, output, and employment in the carpet industry. Government may also consider a permanent change in its policy with regards to subsidizing housing construction, or the Federal Reserve may change the availability of money, which in turn is expected to have an effect on construction starts and the growth of income. Government policies that influence the output of the automobile and the airplane industries also affect the carpet industry, though in a smaller way. Carpet manufacturers and their suppliers are interested in the quantitative effect of such policies and policy changes on the prices and output of their product. The estimation of a value for these impact multipliers is central in answering such questions.

Broadly speaking, the market for carpeting should be viewed in perspective as the market for one product which is closely interrelated with the market for other products, all of which are substitutes to a degree, that fulfill the demand for the general product floor covering. Carpeting competes with resilient flooring, hardwood flooring, and hard surface flooring to satisfy the need for floor covering in the utility function of consumers. Recent figures show that carpeting has increased its share of the floor covering market to an estimated 60% in 1975.

Two developments in the supply side of the market are at the heart of this increased usage of carpeting as the most popular flooring material; the coming about of tufting as the predominant method of manufacture, and the development of synthetic fibers which in turn were used as the face fiber in the carpet. Those two developments lowered the unit cost of production, thereby shifting the supply curve to the right, which in an environment of competition meant declining carpet prices. Substitution and income effects clearly took place, and consumption of carpeting increased.

Carpets and rugs can be classified according to multiplicity of criteria. A carpet is any floor covering material that is directly fastened to the floor and usually covers the entire floor area (from "wall to wall"), while a rug is not fastened to the floor and does not cover the entire floor area. Carpets and rugs were originally manufactured in the U. S. by some sort of weaving method such as Axminster, Wilton, or Velvet. These weaving processes are labor intensive processes where the weavers are specialized in their trade, with long training periods before their being able to weave efficiently. However, in early 1950's the tufted method of manufacture was introduced. This production process requires less skill on the part of labor, as well as being a much faster process. Thus, due to its lowered unit costs of production and its acceptability by consumers, this method of manufacture proliferated to the point that today in excess of 94% of all carpeting sold is tufted.

Carpeting is different sizes. The term broadloom refers to the carpet manufactured in long rolls - 150' to 300' - of widths 6' or more. In excess of 84% of all carpeting manufactured in 1973 was manufactured as broadloom, with about 12% manufactured as rugs 4' x 6' or smaller, and the remaining 4% manufactured in the standard 4' widths of the auto and aereo market.

Synthetic fibers have taken a commanding lead over natural fibers, with expectations that this lead will continue to increase. For example,

in 1965 wool, which is the chief natural fiber used in carpets, constituted 18% of the total face fiber poundage used, with this percentage consistently declining to about 1.2% in 1975. Of the man-made fibers consumed, nylon ranks first with about 71% of the total face fiber usage, and polyester is a distant second with about 12%, and acrylic (plus modacrylic) fibers make up about 7.7% of total carpet face yarns.

The industry is structured along the lines of five sectors: the carpet, yarn, backing, labor and fiber sectors; it is explicitly presumed that changes in value of the variables that exogenously affect a variable determined in one of the sectors will bring about changes in the values of the endogenous variables.

Time Considerations

The objective of this study is to estimate the parameters of the demand and supply functions of carpets and rugs and their inputs. One of the first considerations to resolve is whether the model's parameters are to be estimated from either cross-sectional or time series data or a combination of both. As a practical matter, limitations as to the availability of the data usually resolve this question, as was partially the case in this study. A complete set of cross-sectional data was not available. Some assumptions could be made about the probability that the carpet bought in state i would be consumed in state j, but these assumptions would add to the variability of the disturbance terms of the demand relationships. Thus, due mostly to data limitations, estimation from cross-sectional data was not feasible.

A study based upon annual time series observations is not desirable because an adequate number of observations would require the study to reach back into the early fifties, and there have been severe changes in the method of manufacture and the pattern of ownership of the firms in the industry since then. Tufting, which revolutionized the industry, established itself as the principal method of manufacturing in the late fifties and early sixties, displacing the traditional weaving method. In addition, there has been a steady trend in the industry for the ownership to evolve from family-owned into publicly-held corporations. These two phenomena can be expected to have had a significant effect on the effect on the structure of the industry, and there are no adequate ways to account for these changes in the specification of the model, given the nature of available data. Furthermore, no monthly data is available for the input variables that are expected to be jointly distributed with the output variables. Consequently, the model specification was formulated on a quarterly basis, since adequate data of this type existed.

A simultaneous determination of the endogenous variables is implied. This assumption is a reasonable one due to the nature of the production process and the methods of distribution of carpeting and its inputs. There are not long lags between the decision to produce and the delivery of the product to the market as is typically the case of agricultural commodities. In these commodities, supply in the current period is frequently specified as a function of price in the previous period, while the price in the current period is determined by demand alone. In the carpet industry information on input prices is current, so decisions on current production is made with knowledge of current input prices. In addition, with the time period being a quarter of a year, it is expected that utilization of inputs during the quarter for the production of output during the same quarter depends on current prices of inputs and of outputs; that is, if there are any lags, they are much shorter than a quarter. Thus, if there is a change in the value of an exogenous variable such as imports of man-made fiber products, it is expected that this change will affect price and availability of man-made staple which in turn will affect (in the same period) price and availability of yarn which in turn will affect (again in the same time period) the price and the availability of carpet products; this is the simultaneous nature of the determination of the endogenous variables.

Nature of the Model

The model constructed in this study is of a simultaneous nature, since in the U.S. carpet industry the production process is such that typically there are no long lags between the time when a decision on production is made and its execution occurs, or when a raw material is purchased and when it is consumed in production. Thus it is reasonable to make a priori assumption that quantities and prices of outputs and of inputs are jointly distributed. That is, for a given time period, prices or quantities of outputs are determinants in the demands for inputs, but prices or quantities of inputs are determinants in the supply of outputs, and prices or quantities of one input may be determinants in the demand or supply for other inputs. The nature of the joint distribution is in addition to the usual expectation about the joint distribution of quantities and prices of a particular output (input) due to the interaction between the demand and the supply of the output (input). It is asserted that due to the simultaneous interaction of the model's relationships, an estimating procedure that accounts for these interactions must be used.

In algebraic terms, the model may be written as follows:

$$BY_t + GZ_t = U_t$$

where,

Y_t = column vector of observation of P jointly dependent variables at time t,

Z_t = column vector of observations of K predetermined variables (exogenous and lagged endogenous) at time t,

B, G = PxP and PxK matrices, respectively, of coefficients to be estimated, and

U_t = column vector of observations of P random variables at time t.

The model consists of P structural relationships to be identified that together interact to determine the values of P endogenous variables of interest. In this model, parameters of the structural equations are estimated, and, moreover, the reduced form of the model established is of interest. To obtain this, we observe that if B is non-singular, $B^{-1}BY_t + B^{-1}GZ_t = B^{-1}U_t$, or $Y_t = \pi Z_t + V_t$ is the reduced form of the model where $\pi = -B^{-1}G$, and $V_t = B^{-1}U_t$.

In the reduced form the endogenous variables are expressed explicitly in terms of predetermined variables and estimated coefficients. Thus, it is possible for one to inquire as to the quantitative effect of a change in the value of an exogenous variable on the endogenous variables, and additionally, to predict values of the endogenous variables for given, assumed, or forecasted values of the exogenous variables.

In this study, the endogenous variables of interest are prices and shipments of carpets and rugs and their inputs. The carpet and rug products for which demand and supply relationships are studied are broadloom tufted, broadloom woven, auto and aero carpeting, needle-punched, and 4' x 6' and smaller, while the inputs are fiber, yarn, backing, and labor. Capital is not explicitly considered an input, and this study is essentially short run in nature, where the short run refers to a decision period (of time) in which the capital of the firms is fixed, but other inputs may vary in quantity. In these studies capital is taken as given, and in every time period the static position of the firms is observed and their utilization of the variable inputs recorded.

The empirical model consists of 16 equations and 60 variables, of which 27 are endogenous, 21 are exogenous and 12 are predetermined. Estimation was by two-stage least squares and ordinary least squares.

The Carpet Market

The carpet market sector consists of 12 equations; five demand, five supply, one inventory, and one advertising equation. These latter two are not an integral part of the carpet market per se, but are included with this sector because one is related to the distribution of carpets, while the other is related to their demand; thus, they fit better in this sector than in any of the other sectors. The carpet products under consideration are: tufted broadloom, woven broadloom, needlepunched, and other, auto and aereo, and 4' x 6' and smaller.

The Yarn Market

The yarn market is represented by three equations, one equilibrium condition, and a statement about one of the supply conditions. Spun yarn and filament yarn are competitive inputs and substitution of one for the other occurs to some degree in the carpet yarn market. Additionally, there are differences in the method of distribution that suggest the two yarns be treated separately. Filament yarn on the one hand is sold directly by the fiber producers to carpet manufacturers, whereas spun yarn goes through an additional stage, the spinning stage. Staple is typically sold by fiber producers to yarn spinners who in turn sell to carpet manufacturers, except for yarn spun by carpet manufacturers. There is heavy competition among yarn spinners who react very readily to short run market conditions. This is not the case of the more stable pricing policies of the fiber manufacturers.

It is argued that typically the supply of filament yarn is perfectly elastic which is tantamount to saying that at the predetermined price, consumers of filament yarn can purchase all of the yarn they desire to purchase. This is a consequence of the conditions of excess capacity that have characterized the fiber industry during the period of analysis.

The Backing Market

The two types of backing which are considered in this market are the jute backing and the man-made type. The supply of man-made backing is considered to be perfectly elastic. There has generally been ample supply of this backing during the period of this study. Thus, the price of synthetic backing is considered as predetermined. With jute, the situation is not as clear-cut. Jute is imported from India, Pakistan, and Bangladesh, which accounts for about 85% of the world's jute production. Therefore, the supply of jute is intimately related to

the political developments in those countries. The political conditions were highly unstable during much of the time period bridged by this study, so much so that the supply of jute seems to have alternated between perfect elasticity and perfect inelasticity, which dictates that a reasonable assumption be made. In times of peace, the supply can be assumed to have been perfectly elastic as there is ample supply of jute and labor in those countries, whereas in times of war, the supply can be assumed to have been perfectly inelastic as there was a breakdown of the climate conducive to exporting. U. S. dock strikes have also played a role. For purposes of estimation, we assume that the most typical situation during the period was that of a perfectly elastic supply curve.

The Labor Market

The market for this input is characterized by a predetermined quantity supplied. It has been pointed out by several people that the Dalton area in northwest Georgia produces in excess of 55% of the carpet manufactured, but a shortage of appropriate housing limits the size of the labor force in this area. However, in the production of woven carpeting, the skills necessary to be a carpet weaver require long training periods, so the number of weavers is assumed in the model to be given. Thus, in the labor market quantity will be predetermined, and wage adjustments are allowed to bring the market into equilibrium.

The Fiber Market

One of the aspects of a simultaneous equation model is that it allows for the joint distribution of variables, which is a more realistic and adequate representation of real world behavior. Specifically, in this case, it allows for the joint distribution of quantities of fibers. Thus, it is possible to follow the quantitative effect of a change on a variable that affects prices and quantities of fiber, on prices and quantities of carpet. The fiber sector is represented by one equation, the derived demand equation (derived from the derived demand for spun yarn) for fiber and a statement about supply being perfectly elastic for the reasons of excess capacity outlined in the description of the yarn market. The price of cellulosic staple is included as there is some substitution between noncellulosic and cellulosic fiber in the manufacture of broadwoven goods; this substitution is especially true in the case of blends such as rayon-polyester and others. The quantity of broadwoven goods is considered as being exogenously determined due to income and other characteristics which are of interest in a study of the textile industry, but not in one of the carpet industry. Finally, imports of synthetic fiber products are expected to be inversely related with noncellulosic staple's quantity demanded.

A Stock Adjustment

A stock adjustment model where producers move towards the quantity they want to supply, but because of capital restrictions are unable to completely reach, is more characteristic of the carpet industry's supply response than is the traditional formulation. Therefore, the supply, the inventory, and the advertising equations are specified as a compact set of equations where the only explanatory variables are the ones judged to have a substantial impact on supply. This model is compatible with the assumptions of profit maximization.

The stock adjustment model is based on the hypothesis that at a given price of the output, producers desire to supply a given unobservable quantity; in the context of the model as used in this study, it is a rate adjustment model, which by definition is quantity per unit of time. At the given price, producers desire to bring to the market a certain quantity of carpet per unit of time; for instance, a quarter. Producers desire to adjust the rates (not the stocks) at which they desire to bring the product to the market. Assume a linear relationship

$$Q_1^* = \beta_o + \beta_1 P_t$$

where,

Q_t^* = desired supply during period t,

P_t = price of the output during period t,

β_o, β_1 = unknown parameters.

If the supply during period t-1 was Q_{t-1}, producers due to equipment and manpower limitations, can change production by a fraction of the desired change:

$$(Q_t - Q_{t-1}) = \gamma (Q_t^* - Q_{t-1}),$$

where,

$0 < \gamma < 1$, and Q_t = actual supply in period t.

This fractional change works in the downward as well as in the upward direction since producers are reluctant to rid themselves of labor which they would have to retrain. This fractional flexibility in the downward direction is especially true in the carpet industry where a tight supply of labor is the rule. It might be noted that this hypothesized behavior of manufacturers where current supply is a function of lagged supply is more realistic as it implies smoothed production rates. Substituting Q_t^* from the first equation into the second yields:

$$Q_t = \alpha_o + \alpha_1 P_t + (1 - \gamma) Q_{t-1}$$

where, $\alpha_o = \gamma\beta_o$ and $\alpha_1 = \gamma\beta_1$.

It can be argued that α_1 is the price coefficient of the short run supply, while β_1 is the price coefficient of the long run supply. This assertion seems to place a restriction on the long run supply in the form that its price coefficient must be of the same sign as the one in the short run, which precludes the possibility of increasing returns to scale in the long run. Besides, time series studies are typically interpreted as short run in nature where the rates of utilization of inputs and of output generation are observed for given prices of the inputs and of the output, thereby making it questionable whether long run inferences can be drawn from observing these short run rates. Perhaps what can be said is that α_1 is a better estimator of the short run price parameter than the coefficient estimated by regressing Q_t directly on P_t.

In statistical estimation of cause and effect relationships, it is necessary first that there be recurrent autonomous forces operating to determine the values of the variables. If these forces do not have an autonomy of their own, it is doubtful whether one can measure them successfully. The preliminary estimates of the needle-punched demand and supply price parameter results seemed to bear this out, and thus they were omitted from the model.

In addition to the stock adjustments, a seasonal variable was added as a regressor in the demand equations. The interest in econometric estimation in this study is to measure the net effect, for example, of income on quantity demanded of a particular carpet product. Therefore, the purely seasonal effect of carpet has to be removed to leave the net effect of income.

Results and Summary

Microeconomic theory was used as a foundation upon which to specify a model of the carpet and rug industry. The model constructed consisted primarily of demand and supply equations for various carpet products and their inputs, where the various relationships interacted to jointly determine prices, quantities, and other endogenous variables. These structural equations were then estimated through the use of econometric methods, and inferences were drawn. Finally, the structure was solved for the endogenous variables, which would facilitate forecasting values of the endogenous variables, although this was not done in this study. Due to space limitations, the equations of the model and the empirical results are not presented here, but a general summary is provided.

The model was estimated in two blocks. In the first block, the 14 equations of the carpet, yarn, backing, labor, and fiber markets were estimated with two-stage least squares estimators, while in the second block the inventory and advertising equations were estimated with ordinary least squares estimators. The latter estimation was possible since the levels of inventory and advertising were postulated as functions of predetermined variables alone and the error terms of each equation were assumed to be independent of one another and of the error terms of the equations of the variables in the first block.

Broadly speaking, the results in the estimated structure serve to reinforce the a priori beliefs about the industry's operation. For example, the demand function for tufted broadloom was found to be highly price elastic over the relevant price range, and thus the equilibrium quantity tended to be sensitive to shifts in supply. In addition, industry output was found to be very sensitive to prices of synthetic fibers. The carpet industry has historically been in the fortunate position of utilizing the general decline in fiber prices and thus owes its growth in part to this decline. The effect of this decline was to shift the supply of carpets out and to the right, thus intersecting the relatively flat demand curve at higher quantities than if the demand were relatively steep. The further change in fiber costs will play a significant role in the growth of the industry.

An inference drawn from the model estimates indicated that advertising as viewed from the point of view of the industry as a whole is not a critical variable in determining carpet consumption. Interfirm allocations are a different matter but it is doubtful that even then one firm would sell significantly more than another due to more advertising alone. In other words, advertising does not move carpets as well as price does. The apparent fact that price moves carpets may explain in part the declining trend in the number of pounds of yarn per square yard of carpet that exists in the industry. By "thinning out" the product, carpet manufacturers have been able to lower prices and thus reach a wider market.

Another interesting inference drawn from the model is found in the relationship between residential and commercial markets. If tufted broadloom sales for residential construction (housing starts) and sales from nonresidential construction (office building, etc.) are picking up the contract market, which they largely were until late 1974, then it is interesting to note that the elasticity of demand of nonresidential construction was about twice the elasticity of demand of residential construction. Hence, the carpet industry apparently is more sensitive to relative and percentage

in nonresidential than in residential construction.

Another empirical finding that reinforces a priori beliefs deals with the price cross-elasticity of demand for tufted broadloom and for woven broadloom. The demand for tufted broadloom is more sensitive to changes in woven prices than is the demand for woven broadloom to changes in tufted prices. Some consumers readily shift in and out of the tufted market depending, ceteris paribus, on what woven prices are doing. If woven prices were to decrease enough, a group of consumers will readily switch to woven; if woven prices became too high, these same consumers would return to the tufted market. If tufted prices decrease, ceteris paribus, proportionally fewer consumers will switch away from woven carpets, and if tufted prices increase, fewer consumers will switch into woven; they may well withdraw from the market for carpeting together if the earlier conclusion that price was a very important variable in moving carpets is uniquely true.

Finally, this study is only a beginning stage in the development of a full model of the textile industry of the U. S. Work in underway by the author to develop models for other sectors of the industry, and refinement of this model of the carpet industry will continue.