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Repeat Purchase and Switching Probabilities in the International Wheat Trade*

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Abstract: Models of purchasing behavior are of particular importance in understanding intercountry competition in specific import markets. In this paper, a model was developed which incorporates the impacts of both stationary and non-stationary phenomena on purchasing behavior. The results are illustrated for two important wheat importing countries which have distinctly different characteristics, Japan and the USSR.

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REPEAT PURCHASES AND SWITCHING PROBABILITIES IN THE INTERNATIONAL WHEAT TRADE

I. INTRODUCTION

The purpose of many marketing and trade policies is to increase the probability of repeating purchases, which is sometimes referred to as loyalty. Consequently, the transition probability matrix is crucial to the analysis of interbrand competition and the effectiveness of marketing and trade policies. As an example, pricing policy is an important marketing tool which has an impact on market shares so long as the switching probability between brands is non-zero. The effect of price policies versus other types of policies is dependent on their impact on the transition probability matrix. These methods for understanding purchasing behavior in consumer and industrial products have become standard and in concept are equally applicable to the understanding of purchase behavior in commodity markets. In international trade, the attraction of a commodity for a particular country would be influenced by price, quality, location, trade, and commercial relations (including bilateral trade, long-term agreements, organization of buying/selling agencies etc.).

The stationary Markov model is an example which has been used extensively to explain trade flows in international commodity marketing. Studies in recent years include Dent (wool) and Wilson, Koo and Carter (wheat). In these studies a simple first-order Markov process is typically assumed and repeat purchase probabilities are derived assuming they are stationary (Bierman, Bonini and Hausman). However, interpretation of these results is fraught with problems due to the maintained assumption of stationarity. Factors which are not stationary in international trade in commodities (agricultural) include prices, quality, export availability, and trade relations. Other factors which influence market shares and are typically constant through extended time periods include bilateral trade and political relations, long-term bilateral grain agreements (LTA's), location (a supplier country located relatively close should have a greater 'attractiveness' relative to one located more distant), and organization of the selling (or) buying agency. Factors which are not stationary in the international commodity trade include prices, quality, and export availability.

The purpose of this paper is to develop a model which incorporates the impacts of price on the transition probability matrix. The model is general and can be applied to markets for consumer, industrial or internationally traded goods. The microfoundation of the model is that the probability of a purchase being made is derived from the buyer's stochastic utility maximization. Aggregation from the purchaser to the market is modeled explicitly with specific assumptions made on the distribution across buyers within a market which allows aggregation from the individual buyer to the market. The results are presented here for two important wheat importing countries, Japan and the USSR, each with distinctly different buyer characteristics.[1]

II. MODELING OF PURCHASE DECISIONS

The foundation of a frequently used model is the first–order Markov process which measures "brand loyalty" or "patronage" of the buyer towards the seller's brand. A basic motivation of the Markov model is that purchases are not shifted between suppliers instantaneously, but rather shifts in purchases are made over time. An important assumption of many applications of Markov models is that of stationarity. Assuming stationarity, many applications measure the repeat purchase probability and ignore other important marketing variables such as prices. The important point is that in these models the purchase decision is influenced by stochasticity of choice rather than temporal variability in the marketing mix. Ignoring such phenomena makes estimation more tractable, but results in biased measures of loyalty to the extent that any of these marketing phenomena themselves are nonstationary. Further, results from stationary models have limited

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[1]A forthcoming paper of ours presents and compares the results for a number of importing countries which buy up to eight different 'brands' of wheat from five different countries.

interpretation, aside from perhaps the measurement of long–run (steady state) equilibrium market shares. However, if the system is nonstationary, the steady–state equilibrium depends on price.

There are several important features of the theoretical model which was used to analyze purchasing patterns in individual wheat importing countries.[2] First, a model of purchasing decisions is developed for the individual buyer assuming random utility maximization. Distributional assumptions are then made to facilitate aggregation across buyers within an importing country, which is the unit of observation. A second feature of the model is that two different types of buyers or purchases are assumed, one which is assumed to be not sensitive to prices, the other being sensitive to prices. The former is referred to as the stationary component of the purchase decision and is that which is traditionally observed in applications of the Markov model. The latter is the non–stationary component. The proportion of a purchase decision which is stationary versus that which is non–stationary is a parameter of the model which is estimated. The data which are observed is the market share of imports for the individual importing country. This is comprised of buyers which have various characteristics and potentially different purchase patterns. Through aggregation across individual buyer behavior we are capable of identifying the purchasing characteristics of the market.

The elements of the transition probability matrix are π_{ij} which are defined as the probability of switching from i to j for all the buyers consisting of both the stationary and nonstationary components. The transition probability for each ij combination is the weighted summation of these two components where ϕ_t is the weight:

π_{ij} = Prob (buyer is nonsensitive) • Prob (switching from i to j | buyer is nonsensitive) + Prob (buyer is sensitive) • Prob (switching from i to j | buyer is sensitive).

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[2]The theoretical model and estimation procedure are described here briefly. Greater detail is contained in our forthcoming paper.

This can be restated as:

$$\pi_{ij} = \phi_t \bullet \beta_{ij} + (1-\phi_t)\ {}_j\Theta_t \qquad (1)$$

where: ϕ_t is the proportion of buyers (or the purchase decision) which are not sensitive to changes in prices; β_{ij} is the probability of switching from i to j for the stationary component; and Θ is a measure of switching in response to changes in prices and is defined below.

Market shares and prices for individual brands are observed for each market and prices for each year. Let ${}_jM_t$ be the market share of brand j at time t which is defined as:

$$ {}_jM_t = \sum_{i=1}^{n} \pi_{ij}\ {}_iM_{t-1} \qquad (2)$$

Combining (2) and (1) results in:

$$ {}_jM_t = \phi_t \left(\sum_{j=1}^{n} \beta_{ij}\ {}_iM_{t-1}\right) + (1-\phi_t)_j\Theta_t \qquad (3)$$

$$\text{where } {}_j\Theta_t = \frac{a_j\ P_{jt}^{-\alpha j}\ e_j}{\sum_{j=1}^{n} a_j P_{jt}^{-\alpha j}\ e_j} \qquad (4)$$

P_j is the price of good j; e_j is the error term, and a_j and α_j are parameters. Equations (3) and (4) characterize the complete model. Parameters of the model to be estimated include ϕ, β_{ij}, a_j and α_j. In the special case when $\phi = 0$, then $M_j = \Theta_t$ and is referred to as the "attraction model" in the marketing literature. Several simplifying assumptions are made to make the system estimable and a four stage procedure was developed and used for estimating the parameters of the model.

III. STATISTICAL RESULTS AND INTERPRETATION

Exports from each of the major wheat exporting countries were included. With the exception of the US and to a lesser extent Canada, the exports from each country are dominated by one class. In these cases, exports from each country were used. These include:[3] Australia (AUS), Argentina (ARG), and European Community (EC). Canadian wheat exports are predominantly Canadian Western Red Spring (CWRS), but in the case of the USSR Canadian Western Amber Durum (CWAD) was treated separately. There are five classes exported from the US and each was treated separately: Hard Red Winter (HRW), Hard Red Spring (HRS), Western White (WW), Soft Red Winter (SRW), and Durum (DUR).

For each importing country the classes (brands are used synonymously) which were regularly purchased were included in this analysis. The effect of this is to eliminate brands which were purchased only sporadically; this preserves degrees of freedom, making estimations more tractable. Market shares for each brand were calculated using only the summation of the wheat imports in the included brands as described above. Because of the class specificity, a multitude of data sources were required. Exports from the EC and Argentina were taken from the annual reports of the International Wheat Council (IWC). The annual reports of the Canadian Wheat Board (CWB) and Australian Wheat Board (AWB) were the source of data for exports from these two countries. Exports of the individual classes from the US were from Grain Market News of the USDA.

A time series of FOB (free-on-board) export prices was developed for each brand. Prices for US, EC, and Argentine wheats were taken from the IWC annual reports. Where prices were quoted for multiple originating ports (for selected US classes), the simple mean was used. Canadian and Australian prices are also available from the IWC. However, these are asking prices and in recent years these have diverged substantially from competitor values, so a series of "realized" prices were developed for each of these brands. In the case of Canada the, "Sales Value" from the financial statements of the CWB were used. These are basis "in-store," and annual average fobbing costs were added to create a representative realized FOB price. Similar procedures were used to create a FOB

[3]The acronyms in parentheses are used throughout the text and in presentation of the statistical results.

series for Australian exports. The ASW price prior to deductions for bulk-handling, freight, dockage, and wheat taxes was used. The result is an effective average realized FOB price for ASW. Both of these were converted to US dollars using current exchange rates.

All prices are annual average FOB prices as described above. Those for the EC already reflect the impact of the EC export restitution. However, the published US prices are gross of the EEP subsidy. To adjust for this in the case of the USSR, a weighted average export price was calculated which deducts from the FOB price the value of the EEP bonus paid on the proportion of purchases under EEP in that particular year. Specifically, for each US class j the effective price was derived as:

$P_{jt} = P_{jt}^{FOB} - EEP_{jt}(X_{jt})$ where P_{jt}^{FOB} is the average FOB price for class j in year t; EEP_{jt} is the average export bonus and X_{jt} is the proportion of sales of class j sold under the EEP program in year t. The time period included in this study was 1961/62–1987/88. The EEP program was initiated in the 1985/86 crop year and was used for US sales to the USSR during 1987/88.

Due to the volume of results only selected statistics are presented and then used to derive the transition probability matrix which is explained in detail. The estimated values of ϕ for the current period were .98 and .66 respectively for Japan and the USSR. These results indicate that Japanese purchasing behavior is essentially stationary whereas a larger proportion of purchases by the USSR are price responsive. The estimated values of α is a measure of the responsiveness of market shares to prices. These are shown below for each class:

	Japan	USSR
CWRS	.18	8.65*
WW	.44	—
AUS	.22	3.54*
HRW	–.45	9.00*
HRS	–.85*	—
EC		4.26*
ARG		3.32
CWAD		6.03*

*Indicates significantly different from 0 at the 10% level.

The sensitivity of purchases with respect to prices is reflected in the parameter α. Specifically, it represents how sensitive imports are to price changes for that portion of purchase decision made which is sensitive to prices (i.e., $1-\phi$). There are two ways to interpret the value of α. One is that it is the elasticity of utility (V_j) with respect to price changes from which the logic of a price changes can be evaluated. A decrease in prices (P_j) results in an increase in V_j, which results in an increase in M_j thereby increasing import demand of brand j. The extent of the increase is reflected in the value of α.[4] These results show that in the USSR α is significant and relatively high in value for most brands. The opposite extreme exists in Japan, where ϕ is large and the value of α's are relatively small and in general not significant.

The elements of the stationary component of the transition matrix are referred to as β_{ij}. The diagonal elements are an estimate of the repeat purchase probability—i.e. a measure of loyalty. As a seller, it is desirable to have brands with high loyalty which diminishes the importance (or need) for price cuts to maintain market shares. The off diagonal elements indicate the probability of switching from the row brand to the column brand. The estimated value of the elements of this matrix are shown below for the two countries:

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[4]The parameter α is also the elasticity of changes in market shares with respect to changes in price.

	JAPAN				
	HRS	HRW	WW	CWRS	AUS
HRS	.28	.67	.00	.00	.05
HRW	.21	.18	.16	.23	.22
WW	.00	.26	.27	.24	.23
CWRS	.00	.32	.19	.49	.00
AUS	.22	.00	.27	.12	.39

	USSR					
	CWRS	HRW	CWAD	AUS	ARG	EC
CWRS	.70	.30	.00	.00	.00	.00
HRW	.08	.64	.00	.18	.11	.00
CWAD	.00	.71	.29	.00	.00	.00
AUS	.17	.00	.22	.33	.28	.00
ARG	.45	.32	.06	.00	.17	.00
EC	.00	.00	.00	.00	.00	1.00

Important characteristics of competition between brands in each market can be gleaned from the elements of these matrices. Specifically, stability of the market share for a particular brand can be determined by comparing the summation of the row elements to that of the column elements. Summation of the column elements ($\sum_{i=1}^{n}\beta_{ij}$) is the probability of gaining market share and summation of the row elements ($\sum_{j=1}^{n}\beta_{ij}$) is the probability of losing market share. The difference between these two values ($Z = \sum_{i=1}^{n}\beta_{ij} - \sum_{j=1}^{n}\beta_{ij}$) reflects the net gain or loss in market share from the stationary component of the transition matrix. A negative difference, for example, would indicate the brand has an inherently declining share in that particular market. In this case, price reductions are necessary in order to maintain or increase market share. The opposite is true when a positive difference exists. Those brands with positive values of Z in Japan were CWRS (.08) and HRW (.43) and in the USSR were CWRS (.40) and HRW (.96). These results indicate that for these brands market shares can be maintained or increased without reliance on price decreases.

The logic of the model developed in this paper is that purchase decisions are based on two components which are influenced by both stationary and non-stationary phenomena. The above discussion provided an interpretation of these individual components. The complete transition matrix, however, is comprised of both of these components. Elements of this transition matrix were derived using equation 1 and the estimated parameters. Changes in prices have an impact on this matrix through their impact on θ_j. In the extreme cases where $\alpha = 0$ or $\phi = 1$, then $\pi_{ij} = \beta_{ij}$ and the results are equivalent to the stationary transition matrix. The elements of this matrix provide a description of the purchase behavior and loyalty of buyers to specific brands of wheat in the international market.

The transition probability matrices are shown in Table 1 and 2. The Japanese matrix is presented for the most recent time period because the elements are very stationary, even though in concept the elements change annually in response to price changes. Temporal differences in elements of the matrix depend on the value of α and Θ for particular brands and are reflective of changes in prices. Casual comparisons illustrate the change in interbrand competition, in this case, between two discrete points in time. Interesting observations can be made in the change in the elements of the transition matrix for the USSR which was a recipient of the US EEP program.[5] In the context of the model developed in this paper, this program results in changing the elements of the matrix: specifically the probability of purchasing the targeted type of wheat and/or the probability of switching to the targeted brand from the others. Comparison of the transition probability

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[5]This is a targeted subsidy which has the impact of reducing prices for specific types of US wheat.

TABLE 1. TRANSITION PROBABILITIES FOR JAPAN WHEAT IMPORTS

	HRS	HRW	WW	CWRS	AUS
	1987/88				
HRS	.28	.66	.00	.01	.05
HRW	.21	.19	.16	.23	.22
WW	.00	.26	.27	.24	.23
CWRS	.00	.32	.19	.48	.00
AUS	.22	.01	.26	.13	.38

TABLE 2. TRANSITION PROBABILITIES FOR USSR WHEAT IMPORTS

	CWRS	HRW	CWAD	AUS	ARG	EC
	1974/75					
CWRS	.66	.21	.01	.05	.05	.02
HRW	.43	.33	.01	.12	.09	.02
CWAD	.40	.36	.11	.06	.05	.02
AUS	.46	.09	.09	.18	.15	.02
ARG	.56	.21	.03	.05	.11	.02
EC	.40	.09	.01	.05	.05	.40
	1985/86					
CWRS	.79	.09	.02	.03	.03	.04
HRW	.74	.12	.02	.05	.03	.04
CWAD	.74	.13	.04	.03	.03	.04
AUS	.75	.07	.04	.06	.05	.04
ARG	.77	.09	.02	.03	.04	.04
EC	.74	.07	.02	.03	.03	.12
	1987/88					
CWRS	.32	.65	.00	.01	.01	.01
HRW	.27	.68	.00	.02	.02	.01
CWAD	.26	.69	.03	.01	.01	.01
AUS	.27	.63	.02	.03	.03	.01
ARG	.30	.65	.01	.01	.02	.01
EC	.26	.63	.00	.01	.01	.09

matrix between 1985/86 and 1987/88 indicates the approximate impact of the program on purchase behavior. The program has had substantial impacts on purchase probabilities by the USSR. In the case of the USSR, the program was used beginning in 1987/88. Between these years, the repeat purchase probability for HRW increased from .12 to .68 and there were corresponding increases in each of the switching probabilities to that brand.

Intercountry competitive rivalry can be discerned by comparing the switching probabilities to and from particular brands. This is the same as discussed in conjunction with the results of the stationary component of the transition probability matrix, except that now the observation is conditioned by current prices. The value of Z is calculated as before being equal to the difference between the column and row summation of the elements. The values of Z for the USSR are:

HRW	2.63
CWRS	–.68
AUS	–.91
EC	–.86
ARG	–.89
CWAD	–.95

The important point is that in general for the targeted US classes Z is positive and relatively large indicating a strong and growing market position; and that for most competitive brand, Z is negative.

IV. CONCLUSION AND SUMMARY

Models of purchasing behavior are of particular importance in understanding intercountry competition in specific import markets. This is particularly true as the competitive environment in the international wheat trade has intensified in recent years. In this paper, a model was developed which incorporates the impacts of both stationary and nonstationary phenomena on purchasing behavior. The results are illustrated for two important wheat importing countries which have distinctly different characteristics, Japan and the USSR. The results illustrate that Japanese purchases are essentially stationary meaning a large portion of the purchases are not responsive to prices. Purchases by the USSR, on the other hand, are very responsive to prices which has an important impact on their transition probability matrix. The impacts of the EEP program on US exports to the USSR were identified in terms of changes in the transition probability matrix.

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