MARKETING SCIENCE
Vol. 8, No. 3, Summer 1989
Printed in U.S.A.

MODELING MULTINATIONAL DIFFUSION PATTERNS: AN EFFICIENT METHODOLOGY

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The objective of this study is to develop an econometric model for the diffusion of innovations at the individual country level, but which also allows the parameters of the process to differ systematically across countries. The conceptualization rests on behavioral and spatial theories of diffusion and extends the domain to international markets. The cross-national model of innovation diffusion which is developed highlights substantive differences and similarities among international markets. It also provides estimates for the diffusion parameters, even for countries where sales data are not available, thereby yielding some insights into the nature of the expected diffusion pattern in these countries prior to market entry.
(Estimation; Statistical Techniques; International Marketing; New Products)

Introduction

The theoretical thrust of this paper is within the genre of diffusion research. This paper presents an efficient methodology for analyzing and predicting multinational diffusion patterns. Our objective is to improve upon standard forecasting methods for international marketing, which tend to rely on the premise of analogous diffusion-like effects and patterns across countries (Keegan 1974).

The Bass model of new product growth has been successfully applied to a variety of innovations in the United States (Bass 1969, Nevers 1972, Dodds 1973, Mahajan and Wind 1986, Kalish and Lilien 1986). Attempts to apply the Bass model in the international setting, however, have been relatively unsuccessful.

Two possible explanations for the estimation difficulties have been suggested by Heeler and Hustad (1980). The first explanation is that the model is context-bound and its structure might not be flexible enough to represent multiple diffusion processes that occur in different cultural and environmental contexts. That is, the basic model does not incorporate market-specific variables in explaining diffusion patterns. Even when the basic model is estimable, the parameters presumably have different values that represent differences in socio-cultural environments. Indeed, diffusion theory predicts varying diffusion rates and patterns by country because of differences in social system characteristics (Gatignon and Robertson 1985).

The second possible explanation for the problems encountered in estimating diffusion models in the international context concerns the lack of a sufficiently long time series of data (Heeler and Hustad 1980). The instability of the Bass model parameter estimates when few data points are available has been demonstrated in a number of studies (Bass

0732-2399/89/0803/0231$01.25

1969, Mahajan *et al.* 1986, Tigert and Farivar 1981). Because of the scarcity of systematic information, parameters of diffusion models estimated only with data available in one country may not be reliable in predicting the diffusion pattern in other countries, and many times the model cannot even be estimated (Heeler and Hustad 1980).

The study reported in this article proposes a unifiable methodology to estimate the diffusion process across countries, yet the methodology allows for heterogeneity within social systems, that is, within-country social boundaries. The proposed methodology also enables the prediction of the diffusion rate of a product in a country before the product is introduced in that country, and hence, no sales data are available. Such a methodology reconciles the two viewpoints in international marketing that (1) the fundamental nature of the processes and theories (model specification) are similar, versus the view that (2) environmental and cultural differences necessitate the adoption of specific marketing strategies by country (Douglas 1976, Wind 1967). The methodology also enables us to conduct a direct comparison between country model parameters with an efficient[1] estimation of the determinants of these country differences.

Diffusion patterns may assume various forms. Innovations may diffuse by following a rapid sales acceleration compatible with an exponential pattern (Fourt and Woodlock 1960), a slower logistic (S-shaped) pattern (Bass 1969), or a variety of other shapes and patterns (Eliashberg, Tapiero, and Wind 1987). The patterns are driven by various behavioral concepts and, therefore, surrender themselves to a certain amount of predictability. The mathematical representation of the process of diffusion of innovations follows a process which is typically characterized by two parameters (Bass 1969). These parameters correspond to theoretical notions developed within diffusion theory research (Mahajan and Muller 1979, Lekvall and Wahlbin 1973). The first parameter is related to the tendency of the population to innovate, acting mainly based on external sources of influence, and purchasing independent of the availability of social influence within the social system. The second parameter explicitly captures the internal social influence phenomenon, as a result of the interaction of nonadopters with adopters. We will refer to these two parameters as propensities to innovate and imitate, respectively. This is for the most part consistent with the terminology employed in prior research to describe the two fundamental parameters. Their values determine the shape of the penetration curve and the speed of the diffusion process.

The objective of this study is to present a methodology which models the heterogeneity of different countries, in terms of their propensity to innovate and imitate, within a general and unifiable diffusion framework. The study concentrates on country characteristics associated with patterns of social communication, which are likely to affect the rate and level of diffusion. The methodology suggested is intended to apply globally to all countries. Thus, it is possible to predict the diffusion of an innovation in a country, even before the innovation is introduced, or in the absence of sales data.

The paper is organized as follows. First, we identify country characteristics which are likely to determine innovation diffusion patterns. Next, diffusion theory concepts, based on social communications and spatial theories, are used to identify a set of relevant predictors of diffusion shapes and rates. We then present the proposed methodology in the context of an empirical analysis, and report the results of the estimation of the model for a set of household innovations in a number of European markets. Finally, the findings are discussed and elaborated, followed by a set of suggestions for further research.

Framework for Examining International Diffusion

The diffusion paradigm has been applied extensively in research at the individual country level (Rogers 1983). However, there is only a meager research base which studies the simultaneous diffusion of innovations *across* countries.

[1] We refer here to the statistical efficiency of the estimators.

In the analysis of "market expectations," Heeler and Hustad (1980) provided one of the few international diffusion analyses in the marketing literature. Based on the Bass model of diffusion, they examined how the basic parameters varied by country and found a higher degree of forecasting error with international data versus U.S. data. It is worth noting that their comparison was based on the ability of the model to predict the time of the sales peak, rather than the basic underlying pattern. Heeler and Hustad conclude by suggesting that communication patterns and economic restraints in countries other than the U.S. may explain the differences. However, these explanatory concepts have not been directly related to the Bass model parameters in any formal model.

The present research builds on these ideas in order to develop an explicit model that captures the effects of country characteristics on the diffusion process. An essential concept of diffusion theory relevant to predicting cross-national differences in diffusion is the *source of information* about the innovation. If the most influential source of information is external to the social system—change agents or previous adopters in different social systems—then the diffusion pattern tends to be exponential in shape. Spatial theories of diffusion in the geography literature have also been concerned, however, with the interpersonal communication process. The emphasis has been placed on geographical barriers to communications (Hagerstrand 1953, Brown 1981). The ability to communicate between groups, such as adopters and nonadopters in different geographical locations within the social system, is another necessary condition for the innovation to spread.

The present research relies on a conceptual framework for classifying countries in terms of three primary dimensions. These dimensions are the levels of cosmopolitanism, mobility, and the role of women in the society. The *cosmopolitanism* variable has been studied extensively in diffusion research and found to be useful in the rural sociology, medical, geography and marketing traditions of research. The *mobility* variable underlies much of diffusion theory within geography and is a key variable in enhancing or limiting the spread of an innovation. The *sex roles* variable has not been studied, as such, in diffusion research, although it is related to the transmission of influence in terms of heterophily (information transfer across dissimilar individuals) within a social system and, therefore, to diffusion rates. We now discuss each of these dimensions in more detail.

Cosmopolitanism

The cosmopolitanism variable has its roots in the "cosmopolitan-local" dichotomy proposed by Gouldner (1957). "Cosmopolitans" are individuals oriented beyond their immediate social system, whereas "locals" are oriented toward their immediate social system. Diffusion research relating cosmopolitanism and tendency to innovate generally has documented a positive relationship. This has been found in the rural sociology tradition (Rogers 1983), the organizational behavior tradition (Kimberly and Evanisko 1981), and the consumer behavior/marketing tradition (Robertson 1971). Cosmopolitans may be important transmitters of information about innovations across national boundaries.

The most common operationalization of the cosmopolitanism concept has been in terms of the level of external information activity (Coleman *et al.* 1966; Hage and Dewar 1973; and Kimberly 1978). Measures such as attendance at professional meetings or conventions and travel to demonstration sites frequently have been used. Cosmopolitans are the links to external information for a social system or country.

Access to external information provides information about innovations which have not yet been introduced in the home country. This leads to a greater propensity to innovate in countries that have a high degree of cosmopolitanism. Hence, the more cosmopolitan the members of the population, and the larger the number of inhabitants that are cosmopolitan, the higher is the propensity to innovate. At the same time, however, in highly cosmopolitan countries, limited opportunity is left for imitation processes. This suggests our first premise:

Premise 1. Countries with a higher degree of cosmopolitanism show a greater propensity to innovate and a smaller propensity to imitate.

Mobility

Within the geography tradition of research on diffusion, the focus has been on the spatial context in which diffusion occurs. The classic research in this area by Hagerstrand (1953), and the more recent research by Brown (1981), stresses factors associated with the spatial and temporal spread of innovations within particular environments.

The importance of spatial factors is demonstrated for interpersonal communications, whereby most influence is transferred within local social systems—the "neighborhood effect" in Hagerstrand's terms. Hagerstrand and others have studied both terrestrial and social distance barriers which impede diffusion.

Spatial factors are also important in examining market and infrastructure factors—the availability of retail stores, service, and transportation (Brown, Malecki and Spector 1976). These market and infrastructure factors, which may vary by region and community, are associated with differences in adoption times. In general, the more developed the market/infrastructure factors (such as number of stores and availability of highways), the more rapid the penetration of the social system.

A key underlying dimension of any spatial theory of diffusion is the mobility of the population, since lack of mobility is a barrier to interpersonal communication. Therefore, the following premise is proposed:

Premise 2: Mobility will be positively associated with propensity to imitate, since it increases the opportunity for social interaction.

No premise is made about the effect of mobility and the propensity to innovate, as they appear to be theoretically unrelated.

Sex Roles

The role of women in a society may be an important intracountry, intersocial group communication factor related to both propensities to innovate and imitate. It would be expected that the number of women working outside the home would be associated with higher income levels, resulting in an increased tendency to innovate. However, the literature on the role of working women suggests that the effects on innovation adoption decisions also depend on the nature of the innovation.

Strober and Weinberg (1977, 1980) make the distinction between "time-saving" durables, such as dishwashers, and "time-consuming" durables, such as entertainment innovations. They found no difference in adoption rates for these two types of innovations and actually no effect of working wives on purchase expenditure decisions, beyond income effects. Nonetheless, Galbraith's (1973) theory that working women have less time available for the usage of time-consuming durables leads to the prediction of a negative effect of working women on the propensity to innovate for this class of durable goods' innovations.

In addition to the effect of working women on the propensity to innovate, working women can also affect the propensity to imitate—a relationship that has not been investigated. Most personal influence is transmitted within a network of peers who possess similar demographic characteristics; this is referred to as "homophilous" influence. The probability of such influence is high, simply because people are most likely to interact with similar others. However, some significant level of influence may be "heterophilous," i.e., transmitted among dissimilar people. This may be particularly true for a population characterized as being highly innovative—having no knowledgeable internal social system sources of influence for the innovation—and which must look to external sources. Rogers notes that "heterophilous communication has a special information potential, even though it may be realized only rarely" (1983, p. 275). This may parallel, to some extent, the concept of the "marginal" in the anthropology literature—a person who transcends cultures and is, therefore, critical to the dissemination of innovations (Barnett 1953).

In the consumer behavior literature, Kaigler-Evans, Leavitt and Dickey (1977) have used the notion of a "point of optimal heterophily." This is the balance point between personal contact, which is so similar as to provide minimum new information, versus personal contact which is so dissimilar that communication breaks off. In their research they provide preliminary evidence for the effectiveness of sources who are in this middle range of heterophily.

It is our thesis in the present research that the percentage of women working outside the home constitutes an interesting proxy-variable for sex role patterns within a society, which affects the degree of heterophily within the social system. Because the effect of women in the labor force depends on the innovation (time-saving versus time-consuming), we cannot propose unconditional hypotheses. However, we make the following premise.

Premise 3: The percentage of women in the labor force is negatively related to the propensities to innovate for time-consuming innovations and positively related to the propensity to imitate when the work context provides a level of heterophilous influence.

Methodology

The methodology developed here consists of an econometric version of the Bass (1969) model of diffusion of innovation. Our methodological approach relates the fundamental parameters of the diffusion model to the country determinants, identified and discussed in the previous section. Therefore, the model developed in this paper extends the single time-series based diffusion model to multiple time-series with a simultaneous estimation of the effects of the determinants of the diffusion parameters across time periods and countries. We turn now to describing, first, the data generating model we propose; then, the data base and measurement utilized. The results are presented in the last section.

Model and Estimation Procedure

Model specification. A discrete-time econometric data-generating model is developed. It links the propensities to innovate and imitate with the country-specific determinants—cosmopolitanism, mobility and the role of women. The model specification is similar to the Bass model, except that the notation is extended to recognize the possibility that the innovation diffuses in multiple countries simultaneously. In discrete-time formulation, the model can be written as:

$$x(i, t) - x(i, t-1) = [p(i) + q(i)x(i, t-1)][1 - x(i, t-1)] + u(i, t) \quad \text{where} \quad (1)$$

$x(i, t)$ = cumulative penetration of product in country i at time t ($x(i, t) = Y(i, t)/m(i)$),

$Y(i, t)$ = cumulative sales of product in country i at time t,
$p(i)$ = propensity to innovate in country i,
$q(i)$ = propensity to imitate in country i,
$m(i)$ = market potential in country i,
$u(i, t)$ = disturbance term.

It should be noted that the market potential of country i, $m(i)$, is not assumed in this model to be affected explicitly by country characteristics. In fact, it has been recommended that the market potential be externally estimated (Tigert and Farivar 1981).[2] Consequently, equation (1) describes the dynamic penetration process of an innovation in a country. In this study it is postulated that the fluctuations of the diffusion parameters across countries can be partially "explained" by the social system characteristics as represented by the cosmopolitanism, mobility, and sex role variables.[3] These relationships are explicitly acknowledged in equations (2) and (3):

$$p(i) = Z'(i)g_p + e_p(i), \tag{2}$$

$$q(i) = Z'(i)g_q + e_q(i), \qquad \text{where} \tag{3}$$

$Z(i)$ = vector of country i characteristics, including an element 1 corresponding to a constant,

g_p = vector of coefficients representing the impact of the country characteristics on the propensity to innovate,

g_q = vector of coefficients representing the impact of the country characteristics on the propensity to imitate,

$e_p(i)$, $e_q(i)$ = disturbance terms.

The disturbance terms $e_p(i)$ and $e_q(i)$ might correspond, for example, to nonsystematic differences in the perceptions of the innovation characteristics across various countries. Systematic differences among innovations are not modeled here, because each innovation is analyzed separately (which allows for unconstrained results across products). Thus, equations (1), (2), and (3) represent the totality of the data generating model. It is the addition of equations (2) and (3) to the basic diffusion model, together with the simultaneous estimation of the diffusion model parameters for multiple countries, that enables us to predict the diffusion parameters for some countries where these parameters could not be estimated due to limitations in that country's data.

The basic econometric structure of this model is similar to the models used by Srivastava *et al.* (1985) and Rao and Yamada (1988). Both of these studies, however, investigate patterns of diffusion of innovations in a single market. The variability in the diffusion parameters in our study is not due to the innovation characteristics as in Srivastava *et al.*, since our model is estimated separately for each innovation. Our objective is to explain the variability in diffusion parameters *across* countries, estimating them (the parameters) via a simultaneous generalized least squares approach. The generalized least squares estimation procedure employed by Rao and Yamada (1988) is different from ours in that it applies only to equations that are equivalent to our equations (2) and (3). Srivastava *et al.* (1985) independently estimate first the parameters in equation (1) and then in equations (2) and (3). We employ a generalized least square estimation procedure on all three equations simultaneously considering the covariance structure in equation (1).

Estimation procedure. Once $m(i)$ (the market potential in country i) is estimated, the model expressed in equations (1), (2) and (3) is linear in its parameters. The parameters, however, may vary across countries. The estimation of such a varying coefficient model has been described in Gatignon (1984). Two steps are required to estimate the complete model. First $m(i)$ is estimated for each product and each country separately, using Ordinary Least Squares (OLS) (Bass 1969). Once $m(i)$ is estimated, its value can be used in equation (1) to normalize the sales data and, thus, obtain the values of the dependent and independent variables. The vectors of coefficients g_p and g_q can then be

[2] For managerial purposes, Tigert and Farivar (1981) propose performing sensitivity analysis using values of the market potential, m, subjectively assessed by managers. Given the empirical assessment of the country characteristic effects in this study, we use only values of m estimated from the data.

[3] From an estimation standpoint, any linear constraint can be applied to the parameters (Gatignon 1984). Although we present here the case with no constraint, the empirical section will discuss results when a coefficient is constrained to zero.

estimated via a procedure in which the various parameters of equations (1), (2), and (3) are considered simultaneously.

The simultaneous estimation procedure first involves the estimation of the error term structure of equation (1), when equations (2) and (3) are incorporated in it, thereby yielding estimated values for $p(i)$ and $q(i)$ separately for each country i. The variances and covariances of the disturbance terms in equations (2) and (3) are next obtained, again by separate OLS estimates of these equations using the estimated values of $p(i)$ and $q(i)$. Then, the Generalized Least Square estimators of the two g vectors are obtained, pooling countries and time periods by simultaneously solving equations (1), (2), and (3), given the estimated covariance structure of the disturbances (Gatignon and Hanssens 1987). The Generalized Least Squares estimators thus obtained are asymptotically efficient estimators of the country characteristics's effects.

The coefficients in equations (1), (2), and (3) are estimated simultaneously using data for all countries. The parameters estimated in equations (2) and (3) can be used in association with the values of the characteristics of a country to provide estimates for the basic diffusion parameters. Consequently, the prediction of the propensity to innovate and of the propensity to imitate in a country does not depend on the ability to estimate the basic diffusion model (using OLS) solely with data from that country. Indeed, we later demonstrate how these predictions can be obtained for a country, even before the innovation enters that country.

Data and Measurement

Data on country characteristics and the penetration of various innovations since their introduction in each country are published for European countries in *Euromonitor*.[4] The periods for each country cover a span from 1965 to 1980, although there is a wide variation across products and countries as to the year in which the innovation was introduced.

Penetration data. As indicated earlier the empirical analysis was performed on several products. We report the results of six products for which sufficient data with enough countries and time series were available.[5] These products can be characterized as consumer durables: dishwashers, deepfreezers, lawnmowers, pocket calculators, car radios, and color televisions.

Country characteristics. The three characteristics which, conceptually, should explain different diffusion patterns across countries are the constructs representing cosmopolitanism, mobility, and the role of women in society. Two methodological issues must be resolved in operationalizing and assessing the values of these country characteristics. The first issue concerns an appropriate procedure for summarizing variables that evolve dynamically over time, and the second concerns the measurement of unobservable constructs.

The first concern is that characteristics of a country may vary over time. However, the data employed indicate that the aggregate variables which represent the constructs of interest show little variation, as indicated by their low levels of coefficients of variation during the period of diffusion.[6] Consequently, the mean for each variable was computed

[4] Because of the nature of the data, the study was done using European countries only. Although somewhat restrictive, this could only bias the results conservatively toward insignificance due to the lesser degree of variation that may exist within a geographical area. However, the 14 countries analyzed represent a variety of cultures and demographies. These countries were: Belgium, Denmark, France, West Germany, Italy, the Netherlands, United Kingdom, Austria, Finland, Norway, Portugal, Spain, Sweden, and Switzerland.

[5] Although the complete analysis was also performed for videocassette recorders, none of the coefficients was significant due to the limited number of observations, because of the small number of countries in which VCRs had started to diffuse.

[6] The average coefficient of variation across variables and countries is only 0.63. In addition, this coefficient is consistently greater than one only for foreign travel and foreign visitors, and in general is very small, as

TABLE 1
Country Values for Key Variables

Country	Cosmopolitanism*	Mobility*	Women in Labor Force*
BELGIUM	0.108	0.166	−0.604
DENMARK	0.856	0.487	0.079
FRANCE	0.121	0.320	−0.008
WEST GERMANY	0.301	0.198	0.222
ITALY	−0.049	−0.047	−1.062
NETHERLANDS	0.350	−0.013	−1.330
UNITED KINGDOM	0.556	0.221	0.078
AUSTRIA	0.176	0.344	0.595
FINLAND	0.766	−0.159	0.901
NORWAY	0.821	0.419	−1.089
PORTUGAL	−0.445	−0.145	−1.528
SPAIN	−0.203	−0.027	−2.023
SWEDEN	1.548	0.797	−0.023
SWITZERLAND	0.871	0.536	−0.250

* All the measures are standardized across countries so that each variable mean across country is zero and the variance is one. Only the countries for which sales data were analyzed are reported in this table.

over time to represent the position of each country on that variable during the time horizon of concern, depending on the beginning and the end of the observations for that variable.

Two diffusion determinants, cosmopolitanism and mobility, were measured using multiple item scales, and the third one, sex roles, using a single item. The measurement of cosmopolitanism is similar, in concept, to prior research and is based on six items which assess exposure to information beyond the country boundaries: (1) quantity of foreign mail received, (2) quantity of foreign mail sent, (3) international telegrams received, (4) foreign travel, (5) foreign visitors received, and (6) number of telephones in use. All items are measured per capita to remove population size effects. Mobility is based on three items (1) percentage of population owning at least one car, (2) average number of cars per inhabitant, and (3) per capita mileage driven. These items are used to represent an overall mobility factor within each of the countries in the study.[7]

Table 1 reports the characteristics of the various countries included in this study. By far the most cosmopolitan country is Sweden, followed by Switzerland, Denmark, Norway, and Finland. Portugal, Spain, and Italy are the least cosmopolitan of the 14 countries studied. On the mobility dimension, Sweden, Switzerland, Denmark, and Norway are at the top of the list. Finland shows the least mobility. On the other hand, Finland has the greatest percentage of women in the labor force, followed by Austria and West Germany. Spain, Portugal, and the Netherlands show the lowest levels of working women.

The values of the three country characteristics suggest a reasonable face validity for these scales. However, the percentage of women in the labor force could be confounded, or a surrogate for income. The data show that countries which have high income per

illustrated by the following seven randomly selected coefficients (using random tables): 0.022, 1.31, 0.049, 0.220, 0.098, 0.053, and 0.026.

[7] In order to check the reliability of the multiple item measurement for two of the constructs: cosmopolitanism and mobility, the original items were first standardized across countries. Then, for the two determinants, separate factor analyses confirmed the existence of only one factor with an eigenvalue greater than one. The percentage of explained variance for the cosmopolitanism factor was 68.7% and 89.3% for the mobility factor. In addition, the reliability coefficients (Cronbach coefficient alpha) were respectively 0.94 and 0.90 for the mobility and cosmopolitanism scales (Cronbach 1947).

TABLE 2
Estimated Diffusion Parameters from the First Stage OLS

	Dishwashers			Deep Freezers			Lawnmowers			Pocket Calculators			Car Radios			Color TVs		
	p	*q*	*m*	*p*	*q*	*m*	*p*	*q*	*m*	*p*	*q*	*m*	*p*	*q*	*m*	*p*	*q*	*m*
Belgium				0.06	0.56	1634.51	0.04	0.58	1494.22	0.003	1.01	40196.54	0.06	0.15	4709.81			
Denmark	0.09	0.42	308.84				0.08	0.42	1369.59	0.03	0.69	3693.36	0.07	0.54	1137.83	0.11	0.36	1356.16
France				0.08	0.15	8516.82	0.04	0.52	4301.20	0.03	0.57	29697.61				0.03	0.23	28168.72
W. Germany	0.02	0.25	8044.86	0.03	0.19	18555.28	0.06	0.47	9216.08	0.03	0.69	62780.97	0.23	0.52	47036.92	0.03	0.19	47704.47
Italy	0.04	0.34	3949.19	0.03	0.75	7551.81	0.05	0.57	1628.89	0.009	0.42	104725.65				0.03	0.79	9302.65
Netherlands				0.03	0.52	2196.27	0.06	0.55	2066.54	0.06	1.68	3077.44				0.07	0.58	3278.39
U. Kingdom				0.06	0.17	10920.3	0.07	0.41	17793.63	0.04	0.47	58254.92						
Austria	0.03	0.54	414.53	0.05	0.33	1715.69	0.04	0.56	1011.69	0.001	1.77	1704.1	0.05	0.72	2357.83	0.05	0.47	2255.08
Finland				0.12	0.42	738.07	0.02	0.19	828.26	0.008	0.62	12869.66	0.01	0.24	3840.97	0.07	0.33	1313.71
Norway	0.03	0.08	591.95				0.04	0.64	873.44	0.02	0.84	2644.54	0.09	0.5	560.27	0.06	0.53	1291.77
Portugal				0.03	0.98	482.3												
Spain							0.04	0.51	1618.07				0.11	0.21	5910.21	0.04	0.6	4757.16
Sweden	0.05	0.38	745.26	0.09	0.44	1964.5	0.05	0.5	2276.96	0.08	1.06	4647.73	0.05	0.13	5441.10			
Switzerland				0.07	0.20	1076.90	0.26	0.33	649.27	0.01	0.25	14895.08	0.1	0.14	3004.04			

capita, such as the Netherlands or Switzerland, also have a small percentage of women in the labor force (they have a negative standardized score on this measure). Consequently, the measures employed in this study as country characteristics represent empirically different scales in the sense of discriminant validity, although, theoretically, they may not necessarily be perfectly uncorrelated.[8] In addition, the variability of countries on these constructs justifies their potential value, rather than more conventional variables, such as income and country size, which would not represent the factors captured by our three dimensions.

Results

The results of the first stage Ordinary Least Squares estimation, performed separately for each country and product, lead to the estimated diffusion parameters shown in Table 2. The empty cells represent cases for which the estimated coefficients' signs prevent the computation of the basic diffusion parameters p, q and m.[9] Table 2 also shows the

[8] Indeed, while the correlations between women in the labor force with mobility and cosmopolitanism are moderate (0.36 and 0.50, respectively), mobility and cosmopolitanism show a higher correlation level (0.74). The model's results did not indicate that multicollinearity might have been a problem, since the estimated coefficients were stable and significant (with a few exceptions only).

[9] These parameters are computed from the estimated coefficients of the reduced form equations as in Bass (1969). R square measures of goodness-of-fit based on the estimated parameters reported in Table 2 range between 0.966 and 0.999. Note, however, that some of the estimates for the 'q' parameter vary considerably from the mode. See, for example, the low value for 'q' for Dishwashers in Norway and the 'q' values greater than 1.0 for Pocket Calculators in Belgium, the Netherlands, Austria and Sweden in Table 2. In addition, the 'q' values for Dishwashers in the Netherlands and Finland (in Table 4) appear to be unusually small. Possible explanations for such values are a small number of data points and/or time series data that do not cover the inflection point. Such data tend to yield unstable estimated parameters, and that seems to be the case here.

TABLE 3

*Simultaneous GLS Estimation (g_p, g_q) Results**

Variables	Dish-washers	Deep Freezers	Lawn-mowers	Pocket Calculators	Car Radios	Color Television
Propensity to Innovate						
Constant	0.031	0.054	0.044	0.017	0.051	0.029
	(90.0)	(118.9)	(48.3)	(18.7)	(143.9)	(85.3)
Cosmopolitanism	0.022	0.021	0.031	0.010	0.008	0.061
	(47.9)	(30.9)	(24.0)	(6.87)	(18.0)	(96.2)
Women in Labor Force	0.004	0.018	−0.006	−0.001^{NS}	−0.034	−0.004
	(11.5)	(37.1)	(7.8)	(0.5)	(125.6)	(15.9)
Propensity to Imitate						
Constant	0.341	0.391	0.454	0.727	0.375	0.424
	(108.9)	(108.8)	(334.2)	(39.8)	(98.0)	(153.9)
Cosmopolitanism	−0.321	0.109	−0.190	0.060^{NS}	−0.213	0.010
	(34.2)	(16.1)	(84.3)	(1.7)	(31.1)	(2.12)
Mobility	0.568	−0.402	0.400	−0.010^{NS}	0.311	−0.195
	(28.6)	(35.2)	(134.9)	(0.2)	(27.0)	(25.8)
Women in Labor Force	0.092	−0.182	−0.072	−0.060	0.095	−0.137
	(32.0)	(50.2)	(64.5)	(3.6)	(32.3)	(72.1)
Degrees of Freedom	45	88	105	51	53	60
Goodness-of-Fit Measures						
MSE	0.00084	0.00195	0.00112	0.00568	0.00138	0.00109
MAD	0.02268	0.03115	0.02119	0.03813	0.02807	0.02573

* Numbers in parentheses are t-statistics. All the coefficients are significant at level 0.01 except as indicated (NS Not significant).

estimated market potentials for the various countries. Although they are not part of our premises concerning diffusion patterns, they bear significant managerial implications. When computable, the market potential sizes apear within a reasonable range relative to the current level of sales.

Table 3 gives the results of the simultaneous estimation of equations (1), (2), and (3). The entries in Table 3 correspond to the vectors of coefficients g_p and g_q. It should be noted that the coefficients of mobility on the propensity to innovate have been constrained to zero, since there is no reasonable explanation for a different value, as noted above. As can be seen, most estimated coefficients are statistically significant at the 0.01 level. Only three coefficients are not significant, suggesting that women in the labor force do not affect the propensity to innovate, and that cosmopolitanism and mobility do not affect the propensity to imitate for pocket calculators.[10] The results in Table 3 are first discussed from descriptive and substantive perspectives. Then we address some of the advantages of our model from a methodological point of view.

Substantive Results

In order to examine our premises, the signs and the statistics can be evaluated for each product. However, given the fact that each product is a replicate in our analysis, any general supportive statement about the premises can be made only if the coefficients

[10] R squares are not directly interpretable as a percentage of explained variance when using Generalized Least Squares estimation (Judge *et al.* 1985); thus, they are not reported. However, Table 3 provides two measures of fit, the Mean Squared Error (adjusted for degrees of freedom) and the Mean Absolute Deviation over the estimation sample. These two measures are discussed and compared with Mean Squared Deviation and Mean Absolute Deviation obtained on a prediction sample.

have the same sign across replicates, or if a joint test is provided. Indeed, an overall statistical test can be performed, by considering jointly the six products analyzed.

Dutka (1984) illustrates a procedure proposed by Fisher (1910) and extended by Wallis (1942) to test hypotheses based on replicate findings that take advantage of all the statistical information available from such replicates. Dutka provides an example where single studies do not indicate significant results but all the information over the replicate studies does show statistically significant effects. The procedures can be applied for both one- or two-tail tests. Basically, the significance level (p-value) for each replicate is transformed as the logarithm of its inverse and summed across replicates. The value obtained doubled follows a chi-squared distribution. The degrees of freedom are the number of replicates multiplied by two. If the value obtained exceeds the critical value, the composite test rejects the null hypothesis.

Cosmopolitanism is related positively to the population propensity to innovate for the six products studied. This corresponds to the diffusion theory proposition that consumers who innovate go beyond their social system boundaries. Given the consistency of the signs across products, there is no need to perform a joint test. We can directly conclude that the premise relating positively the impact of cosmopolitanism to the propensity to innovate is supported by the empirical evidence.

The estimated effect of cosmopolitanism on propensity to imitate shows mixed results. Indeed, the signs are mixed with three negative, two positive, and one insignificant. Nevertheless, the joint test supports a negative effect as hypothesized ($\chi^2 = 55.27$, d.f. = 12). The negative relationship suggests that cosmopolitanism is a characteristic of propensity to innovate, rather than propensity to imitate. The more cosmopolitan the inhabitants of a country, the greater the tendency to act as innovators without being influenced by internal social interaction. There are, however, exceptions to such a general tendency. For some products, although the more cosmopolitan population will have a tendency to innovate, this population also plays the role of transmitting information to others. Cosmopolitans who have already adopted the innovation are boundary spanners who influence those who have not adopted yet. This duality of roles played by cosmopolitans is illustrated in the cases of deep freezers and color television, where both coefficients corresponding to the effects of cosmopolitanism on the propensities to innovate and imitate are positive.

The findings in these cases are consistent with Granovetter's (1973, 1982) notion of the strength of weak ties since, without a minimum level of cosmopolitans to adopt an innovation, there cannot be the basis for an imitation effect to occur among peers. Therefore, in general, the conclusion seems to be that the effect of cosmopolitanism on the propensity to imitate is negative. However, the nature of the product can be a determinant of the role of cosmopolitans on this imitation phenomenon.

The effect of mobility on the propensity to imitate also shows a mixed pattern. Three out of the six coefficients correspond to the premise of a positive relationship. The two significant negative coefficients (for freezers and color televisions) could be due to the specificities of these products. Freezers have developed relatively fast in rural areas in most of Europe; factors other than mobility must be introduced to understand why. For color television, availability of program reception through the regions of the country could have originally driven the diffusion, in addition to the unusually high price. Again, in the case of mobility, the product characteristic interacts with the communication factor to explain country differences in diffusion rates, but the overall joint test supports a positive effect ($\chi^2 = 56.35$, d.f. = 12).

The importance of women in the labor force is clear from the results, as all coefficients are statistically significant. However, as indicated earlier, the sign of the effect depends on the specific innovation, because working women do not play a central communication role with respect to all products. This is the case for lawnmowers and color televisions, for example, where both the propensity to innovate and to imitate decrease with increased percentage of women in the labor force. But it is also the case for deep freezers, where, although the likelihood of adoption is independent of social influence and is higher in countries where the percentage of working women is high, the propensity to imitate is smaller. This negative effect of working women on the internal influence phenomenon indicates that working women are not viewed as a key factor in the dissemination of innovations in some product categories.

Although the constant terms were not the concern of any specific premise, their positive signs, their magnitude, and their significant levels are worth noting. Indeed, these are the values of the diffusion model parameters (propensity to innovate and to imitate) for a country characterized by average social characteristics (given that the characteristics are normalized with zero mean). Overall, the magnitude of the diffusion parameters are within the range of typical values reported in the literature (Sultan, Farley, and Lehmann 1988). This indicates that the results of the model, estimated simultaneously across countries, lead to comparable parameters.

Methodological Advantages of Model

As indicated earlier, the proposed methodology enables the estimation of the parameters of the diffusion model, even in cases where these parameters can not be estimated for separate product/country models. Table 2 shows 24 such cases where the entries have been left blank. Table 4 provides the estimated propensities for each country based on equations (2), (3), and the country characteristics. All the estimated propensities fall within typical ranges, with values of the propensity to innovate (p) being much smaller than the values of the propensity to imitate (q).

The complete set of diffusion parameters can be estimated because of the larger degrees of freedom resulting from pooling all observations for one product across countries, and because of the constraints imposed concerning differences in diffusion parameters across countries. If the country characteristics used to predict country diffusion parameters were all equal to zero, the model would reduce to a pure random coefficient model where the stochasticity occurs across countries. Of course, assuming complete homogeneity of coefficients p and q across countries, it would be feasible to use the average of the estimated

TABLE 4

Predicted Coefficients of Propensity to Innovate and Imitate

	Propensity to Innovate Coefficient (p)						Propensity to Imitate Coefficient (q)					
	Dish-washers	Deep Freezers	Lawn-mowers	Pocket Calcu-lators	Car Radios	Color Tele-visions	Dish-washers	Deep Freezers	Lawn-mowers	Pocket Calcu-lators	Car Radios	Color Tele-visions
BELGIUM	0.031	0.045	0.051	0.019	0.073	0.038	0.345	0.446	0.540	0.768	0.346	0.476
DENMARK	0.050	0.074	0.070	0.026	0.055	0.081	0.351	0.274	0.481	0.766	0.351	0.327
FRANCE	0.034	0.056	0.048	0.019	0.052	0.036	0.483	0.274	0.560	0.730	0.448	0.364
WEST GERMANY	0.039	0.064	0.052	0.020	0.046	0.047	0.377	0.304	0.460	0.728	0.393	0.358
ITALY	0.026	0.034	0.049	0.017	0.087	0.031	0.232	0.598	0.521	0.790	0.270	0.578
THE NETHERLANDS	0.034	0.038	0.062	0.022	0.099	0.056	0.099	0.677	0.478	0.830	0.170	0.613
UNITED KINGDOM	0.044	0.067	0.061	0.023	0.053	0.063	0.295	0.348	0.431	0.752	0.332	0.376
AUSTRIA	0.037	0.068	0.046	0.019	0.032	0.037	0.534	0.163	0.516	0.696	0.501	0.278
FINLAND	0.051	0.086	0.062	0.025	0.027	0.072	0.087	0.374	0.181	0.717	0.248	0.339
NORWAY	0.045	0.052	0.075	0.026	0.095	0.084	0.216	0.510	0.544	0.837	0.226	0.501
PORTUGAL	0.016	0.017	0.039	0.014	0.100	0.008	0.261	0.679	0.590	0.797	0.279	0.657
SPAIN	0.019	0.013	0.049	0.016	0.119	0.025	0.205	0.748	0.627	0.841	0.217	0.705
SWEDEN	0.065	0.087	0.091	0.033	0.065	0.124	0.295	0.244	0.481	0.809	0.290	0.289
SWITZERLAND	0.049	0.068	0.072	0.026	0.067	0.083	0.343	0.316	0.521	0.787	0.332	0.363

coefficients for those countries for which they could be estimated as a predictor for the other countries. However, given that this assumption received little support, our model offers two advantages: (1) making use of our stochastic model specification improves the efficiency of the estimators (asymptotically) if the specification is indeed correct, and (2) the incorporation of deterministic predictors of the diffusion parameters reduces the unexplained variance of the parameters across countries. This information can then be used to predict the diffusion rate in any country.

This points to an important benefit of such a simultaneous modeling methodology. The traditional approach provides estimates of the diffusion and sales forecasts only for countries in which sales data are available (and even then, the diffusion parameters cannot always be calculated). Our methodology, on the other hand, provides estimates of the diffusion parameters for *all* countries. Therefore, the methodology can provide estimates for the diffusion parameters in countries that have not adopted the innovation yet, or for countries where data are not readily available, which is a common situation in international marketing research. We turn now to a discussion of forecasting issues based on the methodology.

It is clear that, although it is always possible to predict the diffusion parameters p and q using equations (2) and (3), forecasting sales requires an estimate of the market potential, m. However, as discussed by Heeler and Hustad (1980), management can provide *a priori* sensible limits on the parameter m. Therefore, the following discussion is concerned only with the forecast of the percentage penetration in order to avoid confounding the two separate prediction accuracies (percentage penetration and market potential).

In order to evaluate the degree of accuracy with which penetration level can be forecasted for a country in which the innovation has not yet been introduced or with no data, a series of estimations was performed. Eliminating one country at a time from the data set, a penetration forecast[11] was generated for this country for the first period, based on the estimated p and q parameters derived from the country characteristics and equations (2) and (3). The discrepancy between the forecasted and actual penetration for this period was recorded. Similarly, a forecasted value was obtained for the second period, under the same estimated p and q parameters, but with the use of the actual data point in the first period and based on equation (1). The process continued in this fashion until all data points available for the country had been utilized. Then the discrepancies between the actual and forecasted values were summarized via MSD and MAD measures.

The average mean squared forecast deviation (across products and for each deleted country) and the mean absolute forecast deviation (0.0061 and 0.0071, respectively) can be compared with two fit measures: the average Mean Squared Deviation (MSD) and Mean Absolute Deviation (MAD) obtained for the entire estimation samples (0.0020 and 0.0027, respectively) using the estimated values of p and q reported in Table 4. For comparison purposes, we note that the relative difference between the fit and the forecasting error measures is smaller than that found, for instance, by Mahajan, Mason and Srinivasan (1986) with OLS estimation procedures. A more direct comparison between their results and ours is difficult because the predicted variables are sales and percentage penetration levels, respectively. Consequently, differences in the units of each observation across studies prevent a close comparison of the models. However, we note that the forecast errors in our study are approximately three times larger than the model fit based on the estimation samples. From data reported in Mahajan, Mason and Srinivasan (1986, Tables 8-5 and 8-6, pp. 221–222), the size of their forecast errors is approximately six times larger than the reported fit measures.

An alternative to our methodology is to predict the penetration rates in one country

[11] In the analysis, given that the potential market estimates used are derived from the OLS regression results reported in Table 2, the forecasting is conducted only for those countries for which the parameter m could be estimated. When the parameter m is provided from other information sources, nothing constrains this analysis to be performed over the entire data set.

from the average values of the parameters (p and q) obtained from the other countries for which data are available. These predictions were also performed for all product-country combinations, where the country for which the prediction was made was removed from the average estimate of p and q. The prediction on the holdout sample, based on our methodology, performed better in terms of MSE or MAD measures in 58.3% of the cases. Although the improvement compared with the average values of the diffusion parameters is not dramatic, there is a significant variation across products. Indeed, the percentages are 17%, 64%, 70%, 50%, 56%, and 78% for the six products studied.

To gain additional insight into the source of this variability in the forecasting performance of the proposed model, the performance of the methodology was also compared with the performance of a country level model, estimated by Ordinary Least Squares, but where a number of observations were removed from the estimation sample of each country and used as a holdout sample for the prediction. Clearly, such comparison is feasible only when the model can be estimated, that is, when there are sufficient data points and when the diffusion parameters can be recovered. Consequently, for each country-product combination, a number of time series observations was eliminated. The diffusion parameters were estimated using the GLS estimation procedure corresponding to the proposed model, and they were also estimated separately, using OLS. For the estimation samples, it is clear that the goodness-of-fit measures (MSE and MAD) are better with the individual country models because there is no constraint imposed on the parameters. For the holdout samples, however, a trade-off exists between unconstrained parameters estimated from individual country data versus the stability of the parameters. Indeed, as the time series used for estimation purposes becomes smaller, the mean squared error and mean absolute deviation measures change from more accurate forecasts based on individual country OLS estimations to giving a greater forecasting accuracy to the proposed model.

To illustrate this claim, various analyses were made for each of the six products with a different number of observations in the estimation sample. For example, in Case 1, only the first three observations for each country were included in the estimation sample. In another case (Case 2), only the first four observations for each country were included. Finally, the last three observations for each country were removed from the estimation sample (Case 3). All observations not used for estimation purposes were part of the prediction holdout sample.

The results show that for 80% of the products in Case 1, our model yielded more accurate predictions for the holdout sample with an average MSE of 0.0024 compared with 0.0099 for the country level OLS-based predictions. This percentage is reduced to 17% for Case 2. In Case 3, OLS country level models perform better. Consequently, although the turning point for the trade-off appears specific to a data set, the proposed methodology does seem to be more accurate when few data points are available for the country for which the forecast is needed. Therefore, this methodology seems particularly appropriate before the product introduction in a country, and at the early stages of the product introduction when few data points are available. When the product has already diffused in a number of countries, averaging the country level model parameter estimates performs better, however.

In summary, we conclude that our methodology provides benefits in better understanding international diffusion of innovations, and that the data generally support the importance of incorporating internal social communication factors. The differences in the signs of the coefficients across products indicate that social communication operates somewhat differently depending on the innovation. Although most research on diffusion considers innovation characteristics and social communication factors independently, these results show the need for researching their interactions in the pattern of diffusion. We have shown also that the proposed methodology can provide penetration forecasts, even in the absence (or with a small amount) of data for a given country.

Discussion

This study indicates the existence of some systematic patterns of diffusion across innovations and countries. Although the number of new products analyzed here is limited, the replication of results across the six products suggests a set of significant findings relating cosmopolitanism, mobility, and sex roles to diffusion patterns.

The scope of this study incorporated countries with different characteristics, but the study is not fully representative of the variety of levels of development and cultures existing in the world. Although the operational definitions of the predictor variables might need to be modified, the inclusion of countries with drastic differences in cultures, or in level of development, would refine the theory of innovation diffusion for international marketing. Additional country characteristics are needed to advance our state of knowledge in this area.

In spite of these limitations, the study provides a useful methodology with a model specification based on consumer behavior and spatial diffusion theories for comparing the dissemination of innovations within multiple countries. The empirical results give support to the value of the cosmopolitanism and mobility variables and to the importance of the sex role variable (women employed in the labor force) in shaping the diffusion pattern. This latter variable has not been explored in interpersonal communication diffusion research.

In addition to these theoretical contributions, the results of this study have managerial implications for international marketing. The relationships that have been demonstrated allow the prediction of the diffusion pattern in each country. For example, cosmopolitanism, which was found to be positively related to the propensity to innovate and negatively related to the propensity to imitate, offers the following managerial implication. In countries characterized by a high degree of cosmopolitanism, the diffusion pattern is expected to be more exponential rather than logistic, due to the dominance of external influence.

The model that we have proposed can be a useful forecasting method. Forecasting the penetration of new products is, in general, difficult before the launch of the product (Urban and Hauser 1980). We have demonstrated that the model can use the experience of other countries to forecast the penetration of an innovation in another country, and yet consider individual country differences that systematically affect the penetration curves of similar types of innovation. In particular, predictions can be made concerning the penetration rates before sales data are available. Also, these predictions are more accurate than individual country models when few observations are available for the estimation. Given the speed with which innovations diffuse across countries, this situation faces today's international managers more and more frequently.

In summary, this study represents an attempt to investigate the diffusion patterns of innovations across countries for several products. The empirical analysis for the set of products supports a number of premises. It also provides a useful diagnostic tool for comparing, analyzing, and forecasting country diffusion patterns. In addition to taking an analogical approach to forecasting country diffusion patterns (similar to Easingwood 1987), our methodology provides a useful diagnostic tool for comparing and understanding the determinants of diffusion across countries.[12]

Acknowledgements. This research was supported under a grant from the Pepsico Foundation.

[12] This paper was received in October 1986 and has been with the authors 17 months for 3 revisions. Accepted by Subrata K. Sen.

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