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Innovation Diffusion in a Borderless Global Market: Will the 1992 Unification of the European Community Accelerate Diffusion of New Ideas, Products, and Technologies?

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ABSTRACT

One of the more challenging aspects of the economic unification of the 12 nations of the European Community, initiated on January 1, 1993, is its effects on the diffusion of new ideas, technologies, and products. By becoming "borderless" the European Community should expect to create a global market in which innovation diffusion is faster than if its member countries were not united.

Will unification lead to faster diffusion of new ideas, products, and technologies? To fully answer this question, a diffusion study that compares preunification and postunification diffusion rates is required. Since the unification process is still in progress, the challenge is whether or not we can shed some light on this question based on what we know about the diffusion processes in the European Community countries prior to their unification.

Using a diffusion modeling approach, this article, derives conditions under which unification leads to faster market penetration. In particular, we show that if the innovation diffusion processes in the member nations of the European Community *prior* to unification were similar to one another, no apparent change will be observed in the diffusion of new ideas, technologies, and products in the unified European Community.

We evaluate the above conditions among the member and nonmember nations of the European Community by examining the data on the diffusion of videocassette recorders. The empirical evidence suggests that the diffusion processes do differ among the member and nonmember nations of the European Community and thus the unification should result in faster diffusion of new ideas, technologies, and products.

Introduction

The 1990s marks the first decade when companies around the world have to start thinking globally [10, p. 400]. Increasing economic interdependence and disintegrating barriers to the free flow of information, technology, and money across borders are accelerating the trend toward global market unity. Nations around the world are dismantling their geographic borders to form "borderless markets" that will be increasingly characterized by cooperation, collaboration, and new alliances [14]. The creation of a united European Community, the emergence of new free market economies in the former Soviet bloc

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countries, and the trend toward regional trading blocks are creating new opportunities and challenges that will require multinational corporations to reevaluate their business strategies, resources, and capabilities.

Consider, for example, the 1992 integration of 12 European nations, initiated on January 1, 1993, to form a single European Community. These countries are Belgium, Britain, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. Because of the integration, the European Community is expected to be a border-free zone. People will be able to travel, trade, shop, and settle anywhere within the 12 member nations. The complete economic union including floating of a single currency is expected to be accomplished by the end of the century [2, 3, 7].

The European Community will be comprised of 380 million people with a 7 trillion-dollar-a-year economy that will account for 40% of the world's trade [17]. It will become a megamarket that will be larger than the U.S. market and the second-largest in terms of output level, ranking behind the United States. The integration is expected to save the firms doing business in Europe 15 billion dollars a year that they lose in costs associated with working in 12 currencies [17].

Despite some concerns about its viability [6, 8] the unified Europe is expected to boost competition, breed efficiency, and facilitate cultural interaction. The unification will enable multinational firms to explore opportunities for panEuropean advertising, Eurobranding, consolidation of customer support services and market research budgets, and standardization of products and services. The border-free union will also bring about more cultural interaction among the various countries facilitating increased interpersonal communications among them. Given these expected market dynamics and benefits, it has been hypothesized that the integration of Europe will make market penetration of new ideas, technologies, and products across the 12 nations far easier and faster than if these nations were not unified [13].

Will the integration of Europe lead to faster diffusion of new ideas, products, and technologies? To fully answer this question, a diffusion study that compares preunification and postunification diffusion rates is required. As the unification process is still in progress, rather than waiting for some more years for postunification data, the challenge is whether or not we can shed some light on this question based on what we know now about the diffusion processes in the European Community countries prior to their unification. Using a diffusion modeling approach this article evaluates the hypothesis that the unification of Europe will result in faster market penetration of ideas, technologies, and products across the member nations in the European Community than if these member nations were not unified. More specifically, we derive conditions under which this hypothesis is true. In particular, we show that if the market diffusion processes (as reflected by the external and imitation influences impacting the diffusion process) among the member countries of the European Community prior to unification were similar to one another, no apparent change will be observed in the diffusion of new ideas, technologies, and products in the unified European Community. That is, we show that if the diffusion process is faster in one country than in another, then the joint process for the union will in general be faster than if the countries were not united. We use European data on the diffusion of videocassette recorders (VCRs) to empirically test the conditions of this proposition and to evaluate the unification hypothesis.

The organization of this article is as follows. In the following section we delineate the diffusion modeling approach and present the main proposition, which specifies the conditions for gains in market penetration due to unification. Empirical evidence based

on the European VCR data is presented next. The article concludes with limitations and implications of our approach and results.

The Modeling Approach

UNIFICATION HYPOTHESIS

To articulate the unification hypothesis, for analytical parsimony, we consider a simple case in which a single product is being adopted in two countries, say X and Y, under two different scenarios.

Scenario A describes the situation in which the two countries are independent entities and thus have their own distinct diffusion processes. For this scenario, let

$x(t)$ = cumulative number of adopters of the product at time t in country X

$y(t)$ = cumulative number of adopters of the product at time t in country Y

Scenario B describes the situation in which the two countries are united and their diffusion processes are not independent. For this situation, let

$x_u(t)$ = cumulative number of adopters of the product at time t in country X

$y_u(t)$ = cumulative number of adopters of the product at time t in country Y.

The unification hypothesis states that the market penetration should be higher with unification than without nonunification. That is,

$$(x_u(t) + y_u(t)) > (x(t) + y(t)) \tag{1}$$

Equality in equation (1) will denote no gains in market penetration from unification.

Equation (1) analytically specifies the unification hypothesis for two countries. A similar equation can be written for more than two countries.

TESTING OF UNIFICATION HYPOTHESIS

Given equation (1), the question now is how can we evaluate the unification hypothesis? To do this, we follow the following approach:

1. Based on the Bass [1] diffusion model, we specify diffusion models that capture the diffusion dynamics within and among countries before and after unification.
2. Given diffusion models in step (1), we examine conditions in terms of relationships between parameters of diffusion models of the member countries in the European Community before and after unification that neutralize any gains from unification. That is, we find relationships between diffusion model parameters such that $x_u(t) + y_u(t) = x(t) + y(t)$.
3. In any empirical setting, violations of conditions in step (2) that specify relationships between diffusion model parameters before and after unification such that there are no gains in market penetrations will support the unification hypothesis specified in equation (1).

Conditions Supporting Unification Hypothesis Based on Preunification Diffusion Data

One of the popular models in marketing to describe the growth of a new product is the diffusion model suggested by Bass [1] (For a comprehensive review of diffusion models in marketing, see 11). The Bass model assumes that a new product in a target market is first adopted by a select few potential adopters who then influence the remaining

potential adopters to buy the product [15]. If N and M, respectively, denote the market potential for the two countries X and Y, according to the Bass model the distinct diffusion process within each country before unification can be described by the following differential equations (ignoring argument t for simplicity):

$$\frac{dx}{dt} = \left(a + \frac{bx}{N}\right)(N - x) \tag{2}$$

$$\frac{dy}{dt} = \left(p + \frac{qy}{M}\right)(M - y) \tag{3}$$

Equation (2) describes the rate of diffusion in country X in which the coefficients a and b, respectively, characterize its coefficient of innovation and the coefficient of imitation. Similarly, equation (3) describes the rate of diffusion in country Y with its coefficients of innovation and imitation denoted by p and q. The terms $\frac{bx}{N}(N - x)$ in equation (2) and $\frac{qy}{M}(M - y)$ in equation (3) capture the effect of word-of-mouth interactions in each individual country. The terms $a(N - x)$ and $p(M - y)$ represent the impact of external communication sources.

Equations (2) and (3) need to be modified to represent diffusion processes in the two countries after unification. By supporting a border-free zone of market potential size $(M+N)$, unification permits potential customers and individual adopters in two countries to travel, trade, shop, and settle anywhere in the union. Because of this freedom, it is reasonable to assume that adopters from each country are also likely to influence the remaining potential adopters in the other country. Furthermore, assuming that the level of intensity of this influence, from adopters of each country on the remaining nonadopters in both countries is the same, the rate of diffusion in two countries X and Y after unification can be written as:

$$\frac{dx_u}{dt} = \left(a + \frac{bx_u}{M + N} + q\frac{y_u}{M + N}\right)(N - x_u) \tag{4}$$

$$\frac{dy_u}{dt} = \left(p + q\frac{y_u}{M + N} + b\frac{x_u}{M + N}\right)(M - y_u) \tag{5}$$

The additional terms $q\frac{y_u}{M + N}(N - x_u)$ in equation (4) and $b\frac{x_u}{M + N}(M - y_u)$ in equation (5) identify the incremental contribution to the rate of diffusion of the product in the two countries due to unification. That is, in equation (4) the terms $b\frac{x_u}{M + N}(N - x_u)$ and $q\frac{y_u}{M + N}(N - x_u)$, respectively, represent the word-of-mouth influences of adopters of the product in countries X and Y on the remaining market potential in country X. Similar interpretation holds good for equation (5).

Given equations (2)–(5), the question now is what are the relationships between diffusion models parameters (i.e., a, b, p, and q) that will negate any gains in market penetration due to unification and hence reject the unification hypothesis. In Appendix A we prove the following proposition related to these relationships.

Proposition 1: If $a = p$ and $b = q$, then $x + y = x_u + y_u$.

The above proposition simply states that if the values of the innovation and imitation

coefficients of diffusion models for the individual member countries of the European Community, prior to unification, are identical to one another, then there will be no gains in market penetration in the combined market due to unification. Hence, the violation of the conditions of Proposition 1 will support the unification hypothesis that the unification of the European Community will lead to faster diffusion of new ideas, technologies, and products than nonunification.

Figure 1 shows the implications of Proposition 1 on the market penetration of the product in the combined market of two countries [i.e., equation (1)] after unification for three different sets of diffusion parameters. The data series 1 in Figure 1 assumes the conditions of the proposition. That is, $a = p = 0.02$, $b = q = 0.35$. We also assume that $M = N = 54{,}000$. These values of the diffusion parameters are the averages of the values reported by Bass [1] for the 11 consumer durables he analyzed.

The data series 2 and 3 assume that $a \neq p$ and $b \neq q$. As can be seen from Figure 1, for both of these series diffusion (cumulative adoptions in Figure 1A and noncumulative adoptions in Figure 1B) is faster than when the parameter values are the same. In fact, the larger the difference between q and b, the faster is the penetration. This figure clearly illustrates that the unification hypothesis, equation (1), will be true if the diffusion parameters of the member countries are not the same.

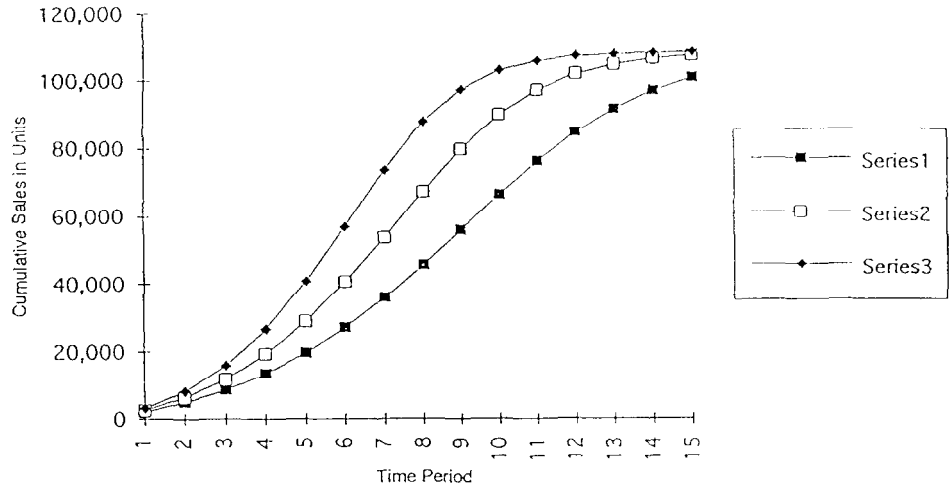
It should be noted that in principle one could argue that the diffusion rate after unification could also be slower and not faster, as is implied by equation (1). The results in Figure 1 clearly show that this indeed does not happen. The larger the difference is in diffusion parameters prior to unification, the faster will be the diffusion after unification.

It should be pointed out here that the unification hypothesis, equation (1), simply states the *direction* of the effect and does not state anything about the *magnitude* of the effect. Assessment of the magnitude of the effect will require a study that compares preunification and postunification diffusion rates. That is, the sum of diffusion data of individual countries prior to unification *does not* describe the postunification diffusion in the union. Hence, rather than waiting for postunification diffusion data, our approach simply evaluates the equality of coefficients of diffusion models of the individual European Community countries prior to their unification to assess the *direction* of the effect.

Empirical Evidence

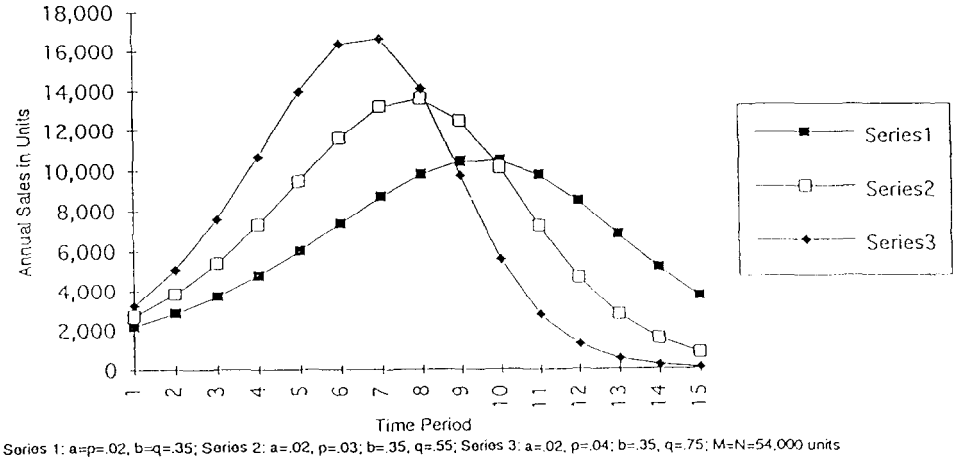
Will unification of the European Community lead to faster market penetration of new ideas, technologies, and products? As explicated in the previous section, according to Proposition 1, the answer to this question depends on whether the model parameters describing the diffusion processes in the member countries are similar to one another. This proposition empirically can be tested by using the approach outlined below:

1. For a product, assuming distinct diffusion processes within each country, estimate the coefficients of innovation and imitation (and the market potential) for each country using the discrete analog of the Bass diffusion model [i.e., equations (2) and (3)] by means of the nonlinear least squares estimation procedures. These estimates may be called unrestricted estimates as they assume no relationships among parameters of different countries.
2. Re-estimate the coefficients of innovation and imitation across all countries by assuming that they are the same for all countries (market potential of course will be different for each country). These estimates may be called restricted estimates.
3. Use the Likelihood Ratio Test (5; for marketing applications, see 12, 4) to evaluate Proposition 1, which assumes that diffusion parameters across nations are not



Series 1: a=p=.02, b=q=.35; Series 2: a=.02, p=.03; b=.35, q=.55; Series 3: a=.02, p=.04; b=.35, q=.75; M=N=54,000 units

(A)



Series 1: a=p=.02, b=q=.35; Series 2: a=.02, p=.03; b=.35, q=.55; Series 3: a=.02, p=.04; b=.35, q=.75; M=N=54,000 units

(B)

Fig. 1. Effect of differences in diffusion model coefficients of two countries on market penetration after their unification. (A) Cumulative sales of a product in two countries after unification. (B) Total annual sales of a product in two countries after unification.

statistically different from each other. This test statistic specifies a chi-square distribution for a multiple (-2) of the difference between the log likelihood of restricted model estimated in step (2) and the unrestricted model estimated in step (1). That is, if L defines the likelihood of a model, then $Q = -2$ (lnL restricted $-$ lnL unrestricted) where Q is distributed as a chi-square distribution with the degrees of freedom given by the difference in the number of parameters between the restricted and unrestricted models (see Appendix B for details of this test). For example, for two countries, since we estimate 6 parameters for the unrestricted model (coefficient of innovation, coefficient of imitation, and the market potential for each country) and 4 parameters for the restricted model

TABLE 1
Countrywise Annual Sales of Video Cassette Recorders (in Thousand Units)

Country	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
EC Countries														
Britain	13	38	165	370	550	2,100	2,379	2,350	2,472	1,950	2,676	2,400	2,100	2,016
Germany	39	85	282	430	650	1,300	1,738	1,780	1,925	1,550	2,429	2,850	2,670	2,630
France	13	21	86	153	310	665	514	555	838	870	1,260	1,630	1,900	1,957
Italy	4	4	27	30	48	95	105	125	305	581	820	1,200	1,370	1,424
Spain	2	3	5	13	30	150	350	410	424	455	651	760	820	861
Belgium	6	7	21	35	46	65	109	140	179	200	276	350	320	332
Denmark	2	5	15	21	32	75	51	75	102	140	128	110	95	96
Netherlands	10	22	28	65	113	300	308	250	380	420	482	530	415	423
Portugal						10	12	35	50	55	115	200	150	156
Greece						11	17	40	55	65	121	190	185	186
Ireland						38	19	65	56	70	69	60	65	66
Other Countries														
Austria	5	6	10	43	37	35	76	90	129	150	209	270	275	266
Norway	1	3	4	13	22	50	40	85	97	140	140	115	120	117
Sweden	6	10	28	80	74	200	65	110	178	220	247	320	300	306
Finland		1	5	7	37	55	99	160	139	120	174	180	155	154
Switzerland		7	7	25	46	60	100	180	183	210	264	285	260	265
Grand Total	101	212	683	1,285	1,995	5,209	5,982	6,450	7,512	7,196	10,061	11,450	11,200	11,255

(one set of coefficients of innovation and imitation and the individual market potentials for the two countries), the degree of freedom is 2. If the value of Q is greater than the critical value of the chi-square distribution at a specified level of significance, we may conclude that the parameters are significantly different from one another and reject Proposition 1. Rejection of Proposition 1 will support the unification hypothesis that the unification of the European Community will lead to faster market penetration than nonunification.

The procedure outlined in steps (1) through (3) can be repeated for any number of products to evaluate Proposition 1 and hence the unification hypothesis. The procedure can be used to compare unification hypothesis between two countries or more than two countries.

To test the unification hypothesis we bought market penetration data for a number of recently introduced consumer durable products (such as microwave ovens, food processors, etc.) from a major consulting company in Europe. Unfortunately, because of different data-reporting procedures and product definition differences across nations, we could not assemble a complete data set for any product since the time of its introduction for all the member countries of the European Community. We were, however, able to assemble data, from 1977 through 1990, for videocassette recorders for 11 European Community countries (exception being Luxembourg), and five other western European countries that are currently not members of the European Community. Even for this product, data for 1985 and 1987 were not available. The data for these 2 years were "created" by using the following procedure: (a) for the missing data for the year t for a country, assume its value to be the average value of the adoption data for years $(t - 1)$ and $(t + 1)$, (b) fit the Bass model to the entire adoption data, (c) estimate new adoption data for year t from the model, (d) reestimate the Bass model using the estimated data for year t and find a new data value for year t, (e) repeat steps (d) and (e) till no incremental change is observed in the adoption data for the year t.

Table 1 includes the adoption data for the 16 European countries (including 11 members of the European Community). These are shown plotted in Figure 2. The market

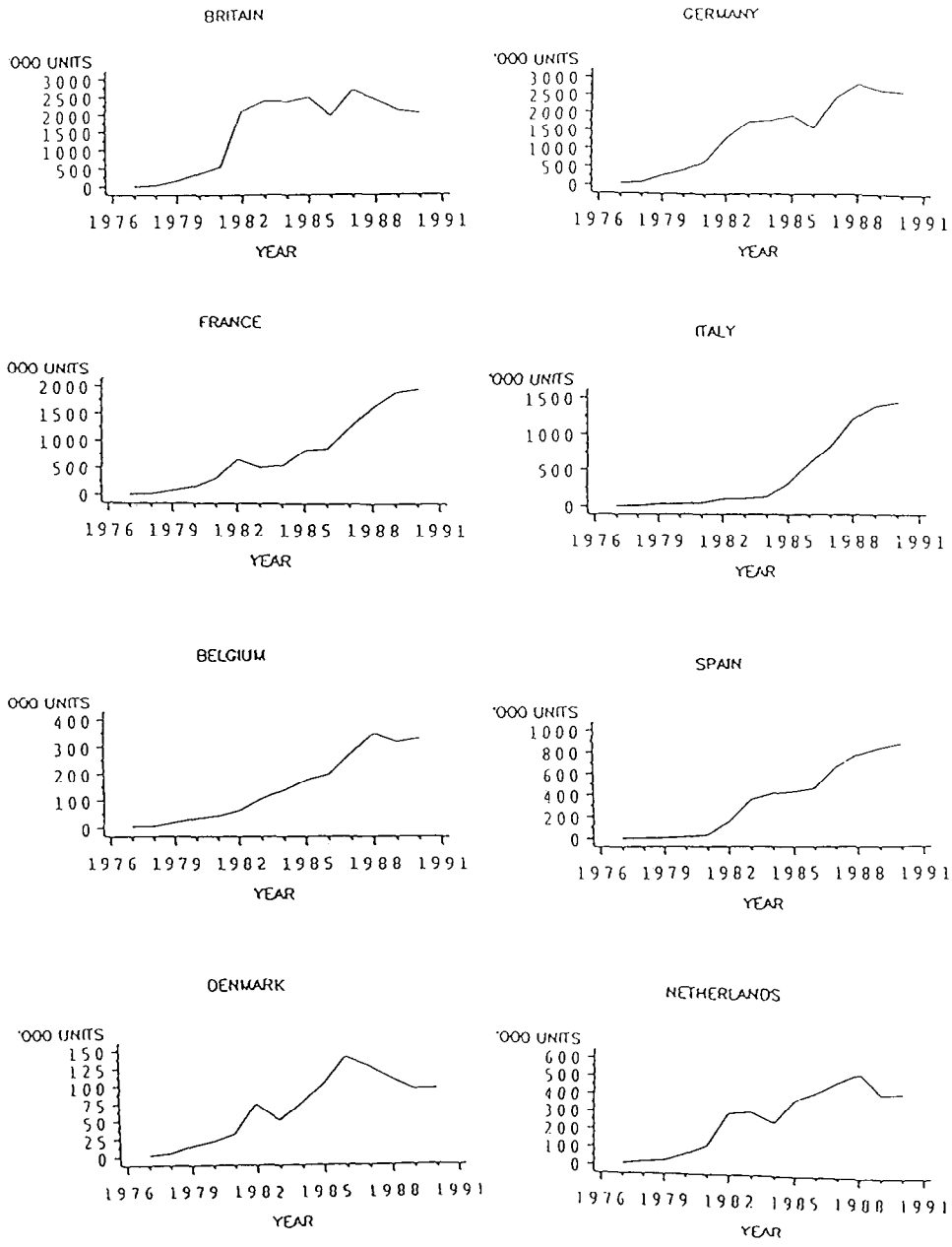


Fig. 2. Countrywise annual sales of video cassette recorders.

penetration plots for the various countries depicted in this Figure are typical of diffusion patterns reported in the literature [e.g., 1, 11] and should be amenable to diffusion analyses desired to evaluate Proposition 1.

Table 2 reports the Bass-model coefficients for the 16 countries. The adjusted-R^2 values indicate that the Bass model describes the data well. Although the coefficient of innovation is not significant (at $\alpha = 0.05$) for a number of these countries, the coefficient of

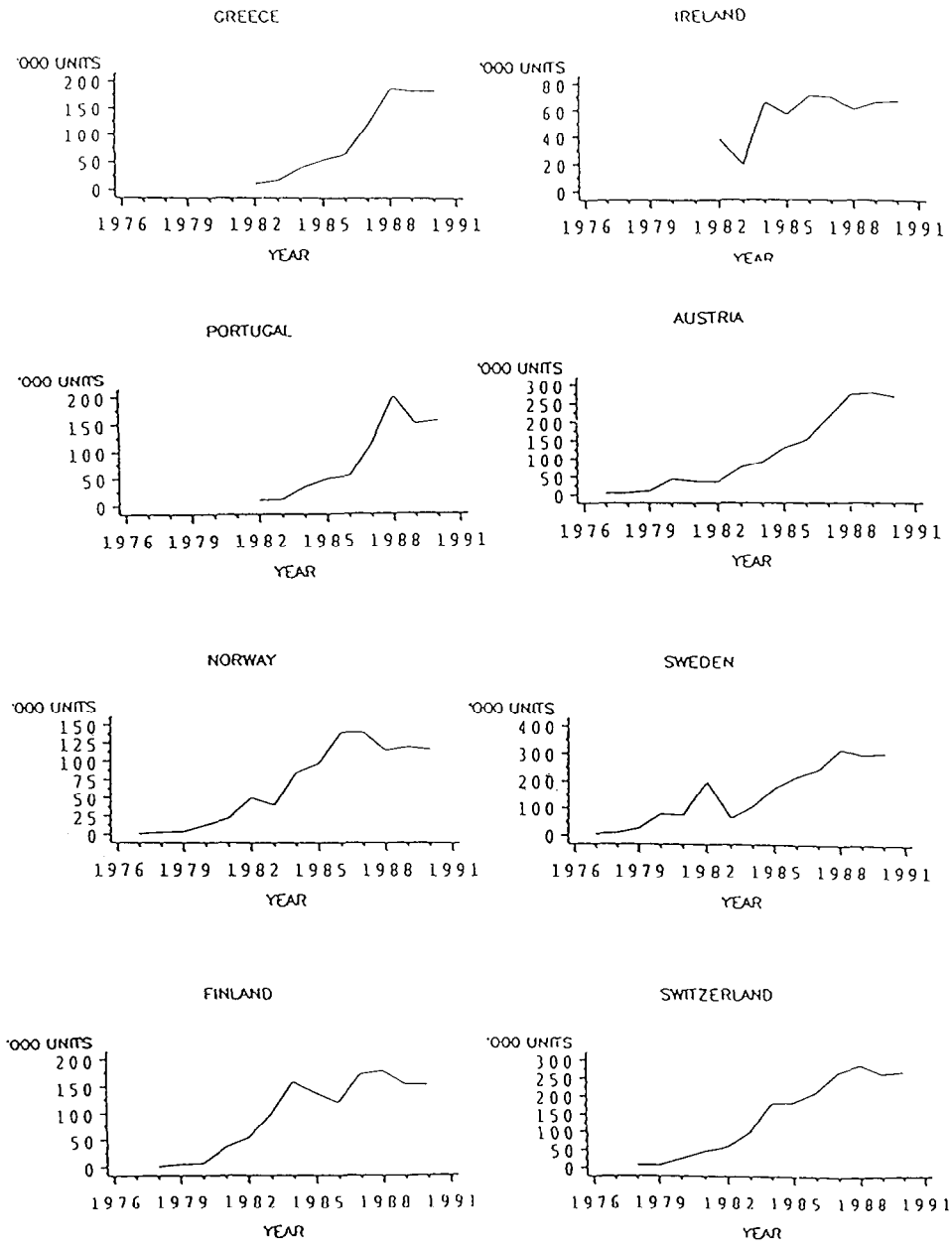


Fig. 2, continued

imitation is significant for all countries except for Ireland. Figure 3 shows these coefficients plotted, for the 16 countries. Several interesting observations are warranted from Figure 3 and Table 2:

1. Among the European Community countries, the significant coefficient of imitation is highest for Portugal, Italy, and Greece and lowest for Germany and France.

TABLE 2
Countrywise Parameter Estimates and Model Fit for Innovation Diffusion Models

Country	Countrywise Estimates a	b	N	Adjusted R-square
EC Countries				
Britain	0.0197	0.4004*	24,613*	0.7545
Germany	0.0118*	0.3364*	29,947*	0.8974
France	0.0049	0.3478*	24,202*	0.9614
Italy	−0.0004	0.7481*	7,831*	0.9936
Spain	0.0088	0.4335*	7,518*	0.9374
Belgium	0.0050*	0.4545*	2,933*	0.9862
Denmark	0.0107	0.4569*	1,075*	0.9131
Netherlands	0.0122	0.4019*	4,654*	0.9014
Portugal	0.0078	0.8340*	863*	0.9089
Greece	0.0093	0.7273*	1,069*	0.9692
Ireland	0.0471*	0.2774	727	0.5411
Other Countries				
Austria	0.0032	0.4653*	2,349*	0.9855
Norway	0.0093	0.5107*	1,081*	0.9372
Sweden	0.0085	0.3076*	3,885*	0.8557
Finland	0.0168	0.4268*	1,560*	0.8463
Switzerland	0.0104*	0.4639*	2,383*	0.9627

Note: *significance (p) value < 0.05.

Data in Table 1 and Figure 1 indicate that VCRs in Portugal and Greece were introduced much later than in the other European Community countries. These observations support findings of Takada and Jain [16] that countries that adopt later tend to have a higher coefficient of imitation. That is, given the product information from other countries, the diffusion processes in the countries that adopt later tend to be dominated by the word-of-mouth effect.

2. The coefficient of imitation is not statistically significant for Ireland. In terms of its magnitude, it is the lowest among all the European Community countries. The

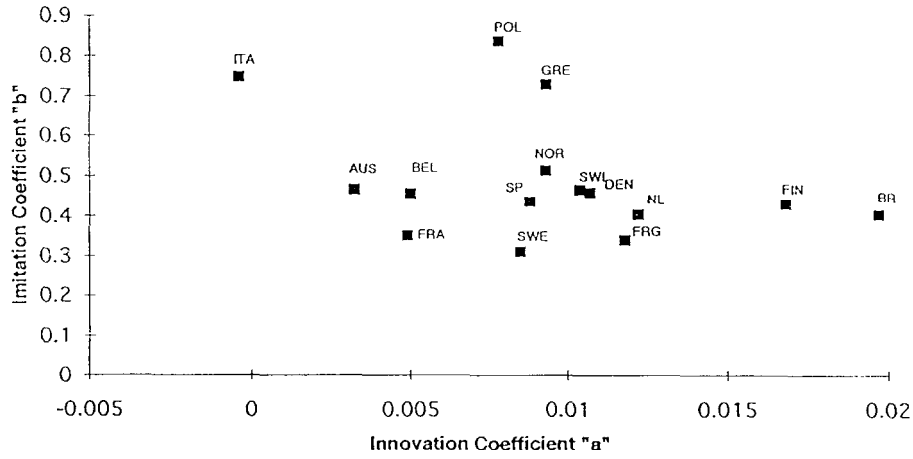


Fig. 3. Countrywise estimates of innovation and imitation coefficients for innovation diffusion models.

TABLE 3
Chi-square Values of Pairwise Model Comparisons for the Likelihood Ratio Tests for Innovation Diffusion Models

	EC Countries										Other Countries				
Country	BR	FRG	FRA	ITA	SP	BEL	DEN	NL	POL	GRE	IRE	AUS	NOR	SWE	FIN	SWI
EC Countries																
Britain (BR)	–															
Germany (FRG)	4.6	–														
France (FRA)	22.9	11.0	–													
Italy (ITA)	53.1	44.7	36.4	–												
Spain (SP)	32.9	20.8	5.0	24.9	–											
Belgium (BEL)	79.4	66.2	42.3	36.8	28.7	–										
Denmark (DEN)	81.7	68.6	44.4	91.0	30.8	1.1	–									
Netherlands (NL)	41.6	29.1	10.2	28.8	1.4	1.3	22.3	–								
Portugal (POL)	61.0	51.6	35.1	15.5	26.6	26.3	22.9	22.1	–							
Greece (GRE)	69.4	60.1	43.1	21.6	33.9	25.0	19.8	28.5	18.8	–						
Ireland (IRE)	71.7	62.3	45.0	26.3	35.5	18.1	15.6	29.4	16.5	28.9	–					
Other Coutnries																
Austria (AUS)	84.7	71.6	47.4	34.7	33.9	0.5	2.0	22.3	29.9	28.0	19.9	–				
Norway (NOR)	82.2	69.0	45.0	88.2	31.4	3.3	0.5	23.2	20.4	28.4	35.5	4.1	–			
Sweden (SWE)	50.0	37.0	14.7	29.6	6.7	17.3	17.6	3.1	20.7	26.0	25.2	21.0	29.3	–		
Finland (FIN)	58.7	46.6	25.1	13.7	13.5	7.5	5.7	7.1	16.8	19.1	17.4	11.5	18.3	5.6	–	
Switzerland (SWI)	65.4	63.6	31.8	22.8	19.1	4.0	1.9	12.2	18.7	18.8	16.5	7.1	44.7	11.3	1.1	–

Note: Countries in pairs with chi-square values less than 5.99 are not significantly different in their parameters at the 5% significance level ($p \leq .05$).

coefficient of innovation for Ireland, however, is highest among all the European countries. The diffusion process for this country seems to be predominantly dominated by external sources of information.

3. Among the five nonmember European countries (Austria, Norway, Sweden, Finland, and Switzerland), the coefficient of imitation is statistically significant for all countries.

To test the unification hypothesis, Table 3 reports the chi-square results for the Likelihood Ratio Test to evaluate Proposition 1 by comparing two countries at a time. Based on the chi-square values reported in this Table, Proposition 1 (i.e., equality of diffusion parameters) is not valid (at $\alpha = 0.05$) for almost all pairs of member countries of the European Community; some exceptions are Germany/United Kingdom, France/Spain, Spain/Netherlands, Belgium/Denmark, and Belgium/Netherlands. When the European Community countries are matched with the other five western European countries, Proposition 1 seems to be valid (at $\alpha = 0.05$) only when (a) Denmark is respectively matched with Austria, Norway, Finland and Switzerland, (b) Belgium is respectively matched with Austria, Norway and Switzerland, and (c) the Netherlands is matched with Sweden.

Overall, the results in Table 3 indicate that, except for some pairs of countries, Proposition 1 cannot be supported for most of the pairs of countries. Hence, the unification even between two countries should accelerate the market diffusion process in the combined market. The question now is whether the unification between the 11 countries of the European Community or all the 16 western European countries included in our analyses would accelerate the market penetration in the unified Europe. When tested, Proposition 1, related to equality of diffusion parameters across nations, could not be supported (at $\alpha = 0.05$) for neither the European Community nor the possible union

of sixteen countries (chi-square is equal to 623.2 for 16 countries with 30 degrees of freedom with the critical chi-square = 43.8 and 386 for 11 European Community countries at 20 degrees of freedom with the critical chi-square value = 31.4). These results clearly support the unification hypothesis that the market penetration will be faster in the borderless Europe.

Conclusions

The integration of European countries in 1992 presents enormous economic opportunities and challenges. The relaxation of regulations in the unified market is expected to enable multinational firms to enhance the efficiency and effectiveness of their marketing programs and production capabilities. One of the hypotheses underlying this optimism is that the unification of Europe will lead to faster market penetration of new ideas, technologies, and products.

In this article, we suggested a systematic approach to evaluate this hypothesis. Based on underpinnings of innovation diffusion models, we indicated that the unification of Europe will not lead to faster market penetration if the Bass diffusion model parameters that capture the dynamics of innovation diffusion for each nation, *prior to unification,* are the same. When tested with the videocassette recorder (VCR) data, this proposition of equality of parameters could not be supported for the European market. Based on these analyses we concluded that the unification of the European Community will facilitate the faster market penetration of new ideas, technologies, and products. Our results are based on only one product. The unavailability of data clearly prohibited us from replicating these results for other products.

It should be noted that our analyses are predominately driven by the communication effects of both the mass media and interpersonal communications. Because the integration of countries will further encourage migration and communication of ideas, technologies, and products across borders, the market as a whole is expected to benefit from these enhanced activities. Other factors such as economic, cultural, and infrastructure differences [9] across nations, are clearly important and may slow down such market benefits. In our analyses we have also assumed that the coefficients of innovation and imitation of individual countries will not change after unification. Even if these coefficients change after unification, so long as their new values (irrespective of their direction of change) are not the same across countries, the diffusion in the union [i.e., equation (1)] will continue to be faster than if these countries were not unified. Of course, only a diffusion study in the future that compares prediffusion and postdiffusion rates will be completely able to shed light on the magnitude of the impact of the unification on the diffusion of new ideas, products, and technologies. Finally, our analyses assume that the preunification and postunification total market potentials for an innovation [i.e., ultimate adoption level $M + N$ in equations (1)–(4)] are the same. This assumption would be invalid if one could argue that the integration of Europe will give a firm access to new markets (e.g., small market in a tiny country) that may not be desirable or available without integration.

The approach suggested in this article is not unique to the unification of Europe. In fact, it can be used to test hypothesized market benefits of any type of integration of markets. In that context, we believe that the article has also made an important secondary contribution to the diffusion modeling area.

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Appendix A

If a = p and b = q then equations (4) and (5) become:

$$dx_u/dt = (a + b(x_u + y_u)/(M + N))(N - x_u) \quad \text{(A1)}$$

$$dy_u/dt = (a + b(x_u + y_u)/(M + N))(M - y_u) \quad \text{(A2)}$$

Let $Z = x_u + y_u$ and thus adding (A1) and (A2) we get

$$dZ/dt = (a + bZ/(M + N))(M + N - Z) \quad \text{(A3)}$$

Let

$$F(t) = (1 - e^{-(a+b)t})/(1 + (b/a)e^{-(a+b)t}) \quad \text{(A4)}$$

The solution of equation (A3) is thus

$$Z(t) = (M + N)F(t) \quad \text{(A5)}$$

while the solutions of (1) and (2) are

$$x(t) = NF(t) \quad \text{(A6)}$$

$$y(t) = MF(t) \quad \text{(A7)}$$

Summing equation (A6) and (A7) we get (A5)

Q.E.D.

Appendix B

To test the hypothesis of equality of parameters "a" and "b" across two countries, let us write the hypotheses as

$$\mathbf{H_o}: \begin{bmatrix} a_1 \\ b_1 \end{bmatrix} = \begin{bmatrix} a_2 \\ b_2 \end{bmatrix} \qquad \mathbf{H_a}: \begin{bmatrix} a_1 \\ b_1 \end{bmatrix} \neq \begin{bmatrix} a_2 \\ b_2 \end{bmatrix}$$

Suppose that the Bass diffusion model is written in the extended form

$$\frac{dx}{dn} = aN + (b - a)x - \left(\frac{b}{N}\right)x^2 + u \quad \text{(B1)}$$

where "u" is a random error term distributed iid $N(0, \sigma^2)$.
Then for "m" observations of country "one", we have

$$\frac{dx_1}{dt} = a_1N_1 + (b_1 - a_1)x_1 - \left(\frac{b_1}{N_1}\right)x_1^2 + u \quad \text{(B2)}$$

Therefore the log likelihood function is

$$\ln L = -\left(\frac{m}{2}\right)\ln(2\pi) - \left(\frac{m}{2}\right)\ln(\sigma^2) - \left(\frac{1}{2\sigma^2}\right)(\mathbf{e}'\mathbf{e}) \quad \text{(B3)}$$

where $\mathbf{e}$ is an $m \times 1$ vector of residuals and $\mathbf{e}'$ is the transpose of $\mathbf{e}$.

As $\dfrac{\mathbf{e}'\mathbf{e}}{m-k} = s_1^2$, and as $E(s_1^2) = \sigma^2$, we have

$$\ln L_1 = -\left(\frac{m}{2}\right)\ln(2\pi) - \left(\frac{m}{2}\right)\ln(s_1^2) - \frac{1}{2}(m - k) \quad \text{(B4)}$$

where "k" (number of parameters estimated) = 3.

Similarly, for n observations for country "two", we have,

$$\ln L_2 = -\left(\frac{n}{2}\right)\ln(2\pi) - \left(\frac{n}{2}\right)\ln(s_2^2) - \frac{1}{2}(n-k) \tag{B5}$$

The sum of the log likelihoods from equations (B4) and (B5) above gives us the loglikelihood of the models written in the unrestricted form with a total of 6 parameters (three for each country).

Let us now consider a restricted model that captures the diffusion process in the two countries but which restricts the innovation and imitation coefficients to be the same for the two countries. In other words, $a_1 = a_2 = a$ (say), and $b_1 = b_2 = b$ (say). The market sizes for the two countries need not be the same to test whether the diffusion process is unchanged by unification of the two countries.

The restricted model is formulated as follows:

$$\frac{dx}{dt} = a(N_1 d_1 + N_2[1-d_1]) + (b-a)x - \left(\frac{b}{N_1 d_1 + N_2(1-d_1)}\right)x^2 + u \tag{B6}$$

where $d_1 = 1$ if observation pertains to country "1"
$= 0$ otherwise

The loglikelihood for the restricted model with "m + n" observations is

$$\ln L_{restricted} = -\left(\frac{m+n}{2}\right)\ln(2\pi) - \left(\frac{m+n}{2}\right)\ln(s^2) - \frac{1}{2}(m+n-2k+2) \tag{B7}$$

The test statistic then is

$$Q = -2(\ln L_{restricted} - \ln L_{unrestricted}) \tag{B8}$$

Q is distributed as a chi-square distribution with 2 degrees of freedom (where 2 is the difference in the number of parameters between the unrestricted and restricted models). If this value of Q is less than the critical value of the chi-square distribution for two degrees of freedom at the 5% significance level, then we may conclude that the parameters are not significantly different between the two countries at this level of significance. Otherwise, we reject the null hypothesis of equality of parameters.

The test for checking the equality of parameters for more than two countries proceeds similarly.

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