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Variable selection in international diffusion models

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ABSTRACT

Prior research comes to different conclusions as to what country characteristics drive diffusion patterns. One prime difficulty that may partially explain this divergence between studies is the sparseness of the data, in terms of the periodicity as well as the number of products and countries, in combination with the large number of potentially influential country characteristics. In face of such sparse data, scholars have used nested models, bivariate models and factor models to explore the role of country covariates. This paper uses Bayesian Lasso and Bayesian Elastic Net variable selection procedures as powerful approaches to identify the most important drivers of differences in Bass diffusion parameters across countries. We find that socio-economic and demographic country covariates (most pronouncedly so, economic wealth and education) have the strongest effect on all diffusion metrics we study. Our findings are a call for marketing scientists to devote greater attention to country covariate selection in international diffusion models, as well as to variable selection in marketing models at large.

1. Introduction

Since the 80s (Heeler & Hustad, 1980), international diffusion of new products has strongly established itself as a research stream within the international marketing literature. International diffusion[1] studies predominantly seek to explain variation in new product growth patterns across countries using country characteristics, such as economics, culture or demographics (for recent contributions, see Chandrasekaran & Tellis, 2008; Talukdar, Sudhir, & Ainslie, 2002; Stremersch & Lemmens, 2009; Stremersch & Tellis, 2004; Tellis, Stremersch, & Yin, 2003; Van den Bulte & Stremersch, 2004; van Everdingen, Fok, & Stremersch, 2009).

An important difference among these studies – beyond the difference in the products or countries included – is the set of country-level covariates included in the model. Model specification in terms of covariates in international diffusion models is particularly challenging. There is no consensus in the literature about which country characteristics should or should not be included in an international diffusion model. Marketing scholars justify their choice for a certain set of explanatory variables by theoretical reasoning. Especially in international diffusion, the theory is very rich and thus the number of variables that one could consider including is very large. At the same time, the data is often sparse, in terms of periodicity, and number of countries and products. Standard statistical estimation techniques often have difficulties to fit such large models on such sparse data. Therefore, scholars may drop one or more of the available variables through subjective choice and iterative testing of smaller models, at the risk of omission.

Scholars who do not restrict their model ex ante, often face ill-conditioning of the design matrix – or harmful multicollinearity – as a significant problem (see Chandrasekaran & Tellis, 2008; Tellis et al., 2003). An ill-conditioned design matrix may pre-empt inference from the full model, by which people resort again to dimensionality reduction techniques, such as estimating nested models (Stremersch & Tellis, 2004), bivariate models (Chandrasekaran & Tellis, 2008), composite models (Gatignon, Eliashberg, & Robertson, 1989) or factor models (Helsen, Jedidi, & Desarbo, 1993; Tellis et al., 2003). Nested models and bivariate models, however, also face the risk of omitted variable bias. Composite and factor models are difficult to interpret and are unable to disentangle the effects of distinct country covariates.

This paper uses Bayesian Lasso (Hans, 2009; Park & Casella, 2008) and Bayesian Elastic Net (Hans, 2011; Li & Lin, 2010) to explore which country characteristics matter most in international diffusion. These procedures can cope with sparse data (i.e., many variables and few data points) by specifying an appropriate informative prior, which leads to a specific form of Bayesian regularization (Fahrmeir, Kneib, & Konrath, 2010). By construction of the Lasso and Elastic Net priors, some of the estimated regression coefficients will be exactly zero, identifying a subset of most important variables. The procedure simultaneously executes shrinkage and variable selection, while alternative

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[1] We use the term international diffusion as a synonym to international new product growth.

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shrinkage methods (e.g. Ridge regression) do not include variable selection and alternative variable selection methods (e.g. Bayesian model averaging) do not include shrinkage. The advantage of the Lasso and Elastic Net procedures over shrinkage methods without variable selection is that it leads to more stable estimation results and to the identification of a relatively small subset of variables that exhibit the strongest effects (Tibshirani, 1996). The advantage over variable selection methods without shrinkage is that the latter methods still lack power in a sparse data setting because the shrinkage is crucial for dealing with correlated covariates, as we show in a simulation study.

We estimate a Bayesian version of the Bass diffusion model (Bass, 1969) which was introduced by Lenk and Rao (1990) and subsequently extended by Talukdar et al. (2002). Bayesian analysis is particularly well suited for international diffusion models because of the multilevel structure of the data. The model decomposes the product- and country-variance, which is important, given that the sample of countries is typically not the same for all products and the product variance is typically larger than the country variance. Also, regularization to deal with sparse data comes natural in a Bayesian setting via the use of an informative prior. Scholars in both marketing (Lenk & Orme, 2009) and statistics (Fahrmeir et al., 2010) show an increasing attention for the usefulness of Bayesian regularization by informative priors.

We have data on the penetration levels of 6 high technology products (CD players, internet, ISDN, mobile phones, personal computers, and video cameras) in a total of 55 countries around the world. These data are also used in van Everdingen et al. (2009) and were graciously made available to us by Yvonne van Everdingen. We complement these data with an extensive set of country characteristics that encompasses the country characteristics used in previous studies on new product adoption, ranging from socio-economic over cultural to demographic and geographic characteristics.

The results indicate that even though many country characteristics have been related to new product growth in the past, in our particular set of countries and products, the following small set of variables explains most of the between-country variation. A first predominant variable is economic wealth. It has a strong positive effect on all three parameters of the Bass diffusion model. A second important variable is education which positively affects both the market potential (m) and the innovation coefficient (p). Beyond economic wealth and education, income inequality has a negative effect on the market potential (m), economic openness affects the innovation coefficient (p), while mobility affects the imitation coefficient (q) in the Bass diffusion model. Future application of variable selection techniques on other samples of international diffusion data, may yield a promising path towards generalizable findings.

2. Prior literature on international diffusion

Table 1 inventories the international diffusion literature using variations of the Bass diffusion model. For every study, we list which country characteristics are studied, whether a dimensionality reduction method is used, and which country characteristics the authors found to influence diffusion. A more general overview of diffusion and new product growth models can be found in Peres, Muller, and Mahajan (2010).

Gatignon et al. (1989) construct three country-level constructs (cosmopolitanism, mobility and sex roles), using 9 variables and find that the three constructs significantly relate to the parameters of the Bass diffusion model. This finding was confirmed in Kumar, Ganesh, and Echambadi (1998). Takada and Jain (1991) use two dummies to account for cultural and communication differences in four Pacific Rim countries and find them to affect the adoption rate. Helsen et al. (1993) cluster countries based on six factors extracted from a total of 23 country characteristics and conclude that life style and health status are related to the parameters of the Bass diffusion model. Dekimpe, Parker, and

Table 1
Overview of international diffusion literature using country characteristics in the Bass diffusion model.

Reference	Included country characteristics	Dimensionality reduction method	Important country characteristics
Gatignon et al. (1989)	Quantity of foreign mail sent and received, international telegrams received, foreign travel, foreign visitors received, number of telephones in use, percentage of population owning at least one car, number of cars per inhabitant, per capita mileage driven, women in labor force.	3 composites: cosmopolitanism, mobility and sex roles	Cosmopolitanism, mobility, sex roles
Takada and Jain (1991)	Culture dummy (high vs low context), communication dummy (homophilous vs heterophilous).	No reduction	Culture dummy, communication dummy
Helsen et al. (1993)	Number of air passengers/km, air cargo, number of newspapers, population, cars per capita, motor gasoline consumption, electricity production, life expectancy, physicians per capita, political stability, imports, exports, GDP per capita, phones per capita, electricity consumption per capita, foreign visitors per capita, tourist expenditures per capita, tourist receipts per capita, consumer price index, newspaper circulation, hospital beds, education expenditures/government budget, graduate education in population per capita.	6 factors: mobility, health status, trade, life style, cosmopolitanism, miscellaneous	Life style, health status
Kumar et al. (1998)	Quantity of foreign mail sent and received, international telegrams received, foreign travel, foreign visitors received, number of telephones in use, percentage of population owning at least one car, number of cars per inhabitant, per capita mileage driven, women in labor force.	3 composites: cosmopolitanism, mobility and sex roles	Cosmopolitanism, mobility, sex roles
Dekimpe et al. (1998)	Population growth, number of population centers, GNP per capita, crude death rate, communism, number of ethnic groups.	No reduction	Population growth, no. population centers, crude death rate, no. ethnic groups
Talukdar et al. (2002)	Income per capita, dependents–working ratio, Gini index, urbanization, international trade, TV penetration, newspapers per capita, illiteracy rate, number of ethnic groups, women in labor force, minutes of international telephone calls.	No reduction	Income per capita, urbanization, international trade, illiteracy
Van den Bulte and Stremersch (2004)	Individualism, uncertainty avoidance, power distance, masculinity, GDP per capita, Gini index.	No reduction	Individualism, uncertainty avoidance, power distance, masculinity, Gini index
Albuquerque et al. (2007)	Population size, GDP per capita, sustainability, literacy, urbanization.	No reduction	Population size

Note: Composites are constructed based on a fixed set of pre-selected country characteristics per construct; factors are obtained by principle component analysis on the complete set of country characteristics; "No reduction" means that all country characteristics are included in the model without transformation.