A Spatio-Temporal Analysis of the Global Diffusion of ISO 9000 and ISO 14000 Certification*

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Abstract

We use the global spread of ISO 9000 and ISO 14000 certification as a context to develop and test a model to examine the spatial and temporal characteristics of cross-country diffusion processes in a unified framework. The central questions in our analysis are whether diffusion of certification is subject to cross-country influences and if so what the nature of that influence is. To answer these questions, we propose a diffusion model which includes several candidate cross-country contagion effects and then use Bayesian methods for estimation and model selection. Using country by year data for 56 countries for 9 years, we find that accounting for cross-country influences improves both the fit and the prediction accuracy for our models of the global diffusion of ISO 9000 and ISO 14000. Interestingly, however, the exact contagion mechanism is different across the two standards. In the case of the ISO 9000 quality standard, geographic distance and bilateral trade flows are the strongest drivers of cross-country effects, while cultural similarity between countries plays less or no role in global diffusion. In contrast, cross-country contagion of the ISO 14000 environmental standard includes a cultural component in addition to the geographical and trade-related ones. We discuss the implications of cross-country influences in the context of the future diffusion of various international management standards that are currently under development.

Keywords: global diffusion, management practice, ISO 9000, ISO 14000, spatio-temporal analysis, Bayesian estimation

1 Introduction

Managers in many leading firms are increasingly concerned about practices in place at their suppliers and other trading partners. In some cases, this concern stems from the fact that poor management practices at suppliers can lead to poor quality of incoming products, which in turn will cause

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problems for the firm and its own downstream customers. In other cases, firms are concerned about unpredictability of supply that can occur if suppliers have poor internal practices. In yet other instances, the concern revolves around the potential negative impact on a firm's reputation if it is associated with suppliers that do not follow appropriate environmental or social practices.

These concerns, combined with the difficulty involved in verifying suppliers' internal practices, led to the emergence of, at first, the ISO 9000 series of quality management systems standards, later followed by various comparable standards.[1] Standards are also emerging for issues that are not immediately related to quality, most notably the ISO 14000 environmental management systems standard. Some firms have also adopted the OHS 18001 standard for occupational health and safety management systems. The ISO/IEC 17799:2000 standard is used for information security management. Social Accountability International administers the SA 8000 standard. ISO itself recently received UN backing to develop standards for social responsibility (ISO 2004).

Most management standards listed above are intended to be adopted globally. Yet, partly due to their relative youth, little is known about how these internationally standardized management practices diffuse across countries.[2] Therefore, this paper proposes a diffusion model of the spatial and temporal mechanisms involved in the global adoption of management standards.[3] In our model, cross-country influences can follow: (1) geography, where one country's adoption depends on past adoption in neighboring countries, (2) bilateral trade, where one country's adoption depends on past adoption in countries to which it exports, and (3) culture, where one country's adoption depends on past adoption in countries which are culturally similar, or (4) any combination of these. The model can be seen as an adaptation of the Bass (1969) diffusion model to include cross-country effects on diffusion. In addition to the cross-country effects, the model concurrently accounts for autonomous growth in domestic certification, and contagion effects of the domestic installed base

[1]Some variations of the ISO 9000 series include the QS 9000 standard for the automotive industry, TL 9000 for the telecommunications industry, and AS 9100 for the aerospace industry. In the food industry, the HACCP (Hazard Analysis and Critical Control Point) system is increasingly becoming a requirement, imposed by governments or customers.

[2]The terms "management standard" and "management practice" are both frequently used to refer to ISO 9000 and ISO 14000. We use "standard" to refer to the written guidelines as published by ISO, and "practice" to refer to the management system implemented by a firm seeking certification to such a standard.

[3]For example, ISO 9000 has spread to 159 countries by 2001 and ISO 14000 to 118 countries by 2003 (ISO 2003).

of ISO 9000 and ISO 14000 certifications. In addition to observed domestic and foreign effects, the model accounts for unobserved heterogeneity in diffusion rates and for omitted variables. We estimate the model parameters using Bayesian methods on data tracking the diffusion of ISO 9000 and ISO 14000 certification across countries and years. The results indicate that cross-country influence is very strong and important for ISO 9000 and ISO 14000 certification. Interestingly, however, the mechanisms giving rise to cross-country influence are different. ISO 9000 certification follows bilateral trade flows and geographic proximity, while for ISO 14000 certification the role of cultural similarity is also important. Taking the cross-country effects into account also leads to substantial improvements in fit and prediction compared to estimating diffusion patterns for each country independently.

This paper aims to make several contributions. First, it adds to our understanding of the spatial and temporal paths by which management practices diffuse across countries. Second, it offers a feasible econometric approach to the estimation of global diffusion processes of management practices. Such an approach needs to deal with the inevitable limitations on the temporal dimension of the data, such as small sample size and missing data on early certification. Our Bayesian estimation method is suited to deal with these limitations and is proposed as a methodological advance in modeling the adoption of management practices. Third, the explicit inclusion of cross-country effects proposed here also constitutes an improvement over existing methods for modeling global diffusion of other products and services, and should therefore be of use to practitioners in marketing and operations who need to forecast future adoption rates and market potentials, based on early and global adoption data.

In Section 2, we review relevant literature on management standards and on global diffusion. Section 3 introduces the temporal and spatial aspects of the model; the data are presented in Section 4. Section 5 explains the estimation and model selection. Section 6 focuses on the cross-country effects, while Section 7 reviews managerial implications of these effects. Section 8 concludes.

2 Literature Review

This study builds on the literature on diffusion of management practices in general and of ISO 9000 and ISO 14000 certification in particular. Methodologically, it draws from literature, mostly in marketing, on models of international diffusion. These streams of literature are reviewed below.

2.1 Diffusion and management standards

Mansfield (1961) is often cited as the first to explicitly model the process with which technology diffuses, using the now well-known logistic function and corresponding S-shaped growth curve. Bass (1969) shows that essentially the same model applies to the diffusion of consumer goods too. Teece (1980) in turn shows that Mansfield's (1961) model also describes the spread of an administrative innovation (the "M-form" organizational structure), hence laying the foundation for studying ISO 9000 and ISO 14000 certification as a diffusion process. Lücke (1993) applies a diffusion model to the spread of process innovations in multiple countries. Strang and Tuma (1993) offer a sociological perspective on the spatio-temporal nature of diffusion processes.

The current literature on the diffusion of ISO 9000 and ISO 14000 certification uses mostly cross-sectional or panel data methods. For instance, Anderson et al. (1999) propose a cross-sectional analysis and suggest that the main reasons for US firms to seek ISO 9000 certification are government requirements, export considerations, internal quality improvements, and cost reduction. The 9-country survey by Corbett (2003) finds that, in late-adopting countries, firms with higher exports are likely to adopt earlier. Similar cross-sectional studies have been conducted on ISO 14000 certification. For instance, using survey data, Christmann and Taylor (2001) find that exports to more developed countries are associated with higher ISO 14000 certification levels among Chinese firms. Corbett and Kirsch (2001) use a cross-sectional regression to suggest that countries with higher exports also have higher ISO 14000 certification levels.

Several studies use the panel structure of country-by-time certification data. Guler et al. (2002) use an 85-country, 6-year dataset of ISO 9000 certificates and find that countries with more investment from abroad and countries with close trade links to other countries with high numbers of certifications have higher certification counts themselves. In the context of ISO 14000, Neumayer and Perkins (2004) use a panel data study of 142 countries to find that certifications per capita are positively correlated with, among others, stock of foreign direct investment and exports to Europe and Japan. Several other studies, not listed here for brevity, adopt variations on the data and methods above.

Rather than using cross-sectional or panel data methods, this study uses a diffusion model to track the certification data. This departure from the current literature on ISO 9000 and ISO 14000 certification is important in two ways. First, a diffusion model focuses on yearly differences in certification rather than on their levels. In the ISO 9000 and ISO 14000 certification context, we believe this is appropriate because the time and money involved in obtaining initial certification is sunk and large compared to the costs of renewing certification. It is thus the timing of the initial certification decision that is informative of the extent of external influence, not the timing of the renewal decision. Therefore, it is natural to focus on the new certifications or the yearly growth in certification if the goal is to test for external influences on the certification decision. Second, if most initial certifications are renewed (as is the case for ISO 9000 and ISO 14000 certification), the yearly certification levels are cumulative variables. Such variables are not mean reverting. A seminal result in Newbold and Granger (1974) shows that regressions among variables that are not mean reverting often show statistically significant results where none are present. This result applies to the case where certification levels in one country are shown to statistically depend on certification levels in another. The standard solution to this so-called spurious regression effect is to difference the time series, i.e., focus on annual growth in certification rather than levels. In sum, we contribute to the literature on ISO 9000 and ISO 14000 by being the first to explicitly model the global spread of these standards as a diffusion process.

Substantively, a recurrent finding in the literature on ISO 9000 and ISO 14000 certification is that trade flows increase certification. While this relationship is plausible, the literature on ISO 9000 and ISO 14000 certification does not consider several alternative explanations. For instance, it is likely that firms export more to countries that are geographically close or that are culturally similar. The association found so far between trade flows and certification may simply reflect that certification diffuses across countries through geographic proximity or cultural similarity. To formally test which of these three mechanisms dominates, we propose a methodology that explicitly nests all three explanations separately or in combination.

2.2 Multi-country and cross-country diffusion

There is a literature in marketing on international diffusion which focuses on two main themes: (1) measuring heterogeneity in country-specific diffusion rates and (2) measuring cross-country contagion. As examples of the former, Gatignon et al. (1989) study national adoption rates as a function of underlying country characteristics, such as cosmopolitanism, mobility and women in the labor force. They conclude that country-specific market potentials, innovation and imitation parameters are all significantly different across six different categories of durable products in 14 European countries. Talukdar et al. (2002) present a diffusion model that investigates the diffusion of six durable products across 31 countries. They use a Bayesian hierarchical model to allow information from other countries and products to help predict market potential and coefficients of imitation and innovation in countries where the diffusion process is in its early stages and/or where there is a lack of information. In their hierarchical model, the parameters of the diffusion model are defined as a function of macro-environmental variables, such as ability to pay, population homogeneity and populations' access to information. Putsis et al. (1997) do allow for cross-country imitation effects and model the "installed-base effect" on adoption as a combination of both within- and cross-country imitation, using information about four categories of durable goods across 10 countries in Europe. Their findings show that diffusion of a product in one country may positively influence the diffusion in other countries.

Our work differs from the above studies in several important ways. First, our paper combines the key strengths of both streams of international diffusion research by focusing on cross-country contagion while properly accounting for observed and unobserved heterogeneity in country-specific diffusion rates. Second, from a substantive point of view, it deals with the diffusion of management standards for which often shorter time series are available than for consumer goods (see e.g., Guler et al. 2002). Our estimation methodology is uniquely suited to deal with this problem. Third, in the context of ISO 9000 and ISO 14000 certification, our study is the first to undertake a systematic model evaluation based on hold-out predictions and fit-tests that warrant against overfitting.

3 Modeling the global diffusion process

3.1 Features of the diffusion model

We focus on ISO 9000 and ISO 14000 certification levels by country and by year, particularly on the temporal and cross-sectional aspects of diffusion. Our model has four distinguishing features, each of which can be operationalized in several ways. First, it accounts for differing degrees and duration of cross-country influence, defined as the effect of past certifications in one country on current certification in another. Two versions of the model are estimated depending on whether only recent certifications or all past certifications can influence current new certifications.

Second, the model allows for alternative interpretations of which countries influence each other. We consider four definitions of what constitutes an "influence set" of nations based on geography, trade relations, cultural similarity, or a combination of these.

Third, the model includes an econometric control for omitted variables in the development of certification levels per country. This is accomplished by allowing for contemporaneous correlation of unobserved factors across geography (see e.g. Anselin 1988). For instance, some relevant factors that contribute to the diffusion of certifications may be at the level of economic regions such as the EU or NAFTA. Any such factor that creates a multicountry "trend" in ISO 9000 or ISO 14000 certification will cause contemporaneous correlation when omitted. We specify two versions of our model, one with and one without contemporaneously correlated errors.

Finally, to ensure that what we measure as cross-country influence is not simply a form of unobserved heterogeneity, we allow for unobserved country heterogeneity by estimating models with random (country-specific) effects. Again, two versions of the model are specified, one flexible model with random effects and one more restrictive model with fixed effects.

These four dimensions of model specification lead to a total design of $2 \times 4 \times 2 \times 2 = 32$ models, each of which is estimated for both ISO 9000 and ISO 14000.[4] The following subsections focus on each of the four model design dimensions: (1) the modeling of cross-country effects in a diffusion model, (2) alternative definitions of neighboring sets, (3) contemporaneous correlation in errors, and (4) unobserved heterogeneity in the model parameters. We present the model in the context of ISO 9000; the models for ISO 14000 are analogous.

3.2 The multicountry diffusion model

We start by defining a multicountry Bass model where the cross-country imitation effects are based on the cumulative number of certifications in other countries. The process that underlies this extension of the Bass model is one where firms are influenced by other firms, at home and abroad, that have received certification in past periods. We model the number of new certifications c_{kt} in country k at time t as:

$$c_{kt} = \left(p_k + \sum_{k'=1}^{K} q_{kk'} \frac{C_{k',t-1}}{M_{k'}} \right) (M_k - C_{k,t-1}) + e_{kt}, \tag{1}$$

where C_{kt} (c_{kt}) is the cumulative (incremental) number of certifications in country $k = 1, ..., K$ at time $t = 1, ..., T$, p_k is called the *coefficient of innovation* and $q_{kk'}$ is the *contagion* effect of past adoption in country k' on current adoption in country k. Further, M_k is called the *potential* for the total number of certifications and e_{kt} is the error term. In order to allow for heteroskedastic errors, we assume that the e_{kt} are normally distributed with mean zero and variance proportional to the previous year's net growth of certifications.[5]

$$e_{kt} \sim N\left(0, \sigma_e^2 \cdot |c_{k,t-1}|\right). \tag{2}$$

We set $c_{k,t-1} = 1$ for the few cases where $c_{k,t-1} = 0$. The resulting model is an extension of the original Bass model, accounting for cross-country imitation effects and allowing the diffusion of

[4]Using all combinations of random-effects (yes/no) with omitted-variables control (yes/no), we additionally estimate four specifications without cross-country effects.

[5]We note that this additive and heteroskedastic residual term is a simple and parsimonious way to account for the empirical patterns in our data: (1) the residuals in the UK (a country with many certifications) have higher variance than those in Hungary (a country with relatively few certifications), (2) the residuals during the first years of certification in say China when it did not have many certifications are smaller than in later years (when many certifications had accumulated), and (3) in very rare occasions, reflecting measurement error and occasional delisting, c_{kt} can be 0 or negative in the ISO data.

ISO 9000 certification in one country to be influenced by past adoption in other countries. The parameters to be estimated are p_k, $q_{kk'}$, M_k and the error variance σ_e^2. Note that if $p_k > 0$ and $q_{kk'} \geq 0$, the cumulative number of certifications will converge to M_k as $t \to \infty$, as in the original Bass model.

An alternative assumption is that cross-country contagion is driven only by recent certifications in other countries. In this view, a firm only exerts influence on firms in other countries soon after its own certification process; some time after certification is complete, there is no residual cross-country influence. This is consistent with the expectation that managers in different countries are more likely to transmit information about recent or ongoing projects than about older events. Therefore, we also examine a model where the cross-country effects depend on the number of recent certifications in other countries, instead of those countries' cumulative certifications:

$$c_{kt} = \left(p_k + q_{kk} \frac{C_{k,t-1}}{M_k} + \sum_{k'=1,\ldots,K;k' \neq k} q_{kk'} \frac{c_{k',t-1}}{M_{k'}} \right) (M_k - C_{k,t-1}) + e_{kt}. \tag{3}$$

Note that the within-country contagion effects still depend on cumulative adoption, in order to maintain the structure and spirit of the traditional S-shaped diffusion curve.

3.3 Cross-country influence

In this section, we define the cross-country effects $q_{kk'}$, which depend on so-called neighbor sets. A country's neighbor set specifies the countries that are hypothesized to affect adoption in that country. We use three definitions of neighbor sets and maintain the term "neighbor set" even when the underlying definition is not geographical.

Geographic distance In this definition, the neighbor set is defined by the closest neighbors in terms of physical distance. This notion of influence is appropriate if ISO 9000 diffusion follows geographical patterns, for instance starting in Western Europe, then spreading West, South and East from there. For each country k, we define the neighbor set $G_k(n)$ as the n geographically closest countries, where distance between countries is measured as the surface distance between country capitals. $G_k(n)$ is the set of countries that are assumed to influence adoption of ISO 9000 certification in country k.[6] The contagion effects in equations (1) and (3) are specified accordingly:

$$q^G_{kk'} = \begin{cases} \lambda^G_k & \text{if} \quad k' = k \\ \gamma^G_k & \text{if} \quad k' \in G_k(n) \\ 0 & \quad\text{otherwise} \end{cases} \tag{4}$$

Testing for geographical cross-country influence is equivalent to testing that $\gamma^G_k > 0$. An appropriate value for n is determined empirically on the basis of model fit.

Bilateral trade Cross-country influence on the basis of bilateral trade data is based on the idea that if a larger share of country k's exports go to country k', then country k' has more influence on adoption in country k. To allow for such influences, we define a variable for the share of exports, $BT_{kk'}$, as follows:

$$BT_{kk'} = \frac{\text{Exports}_{kk'}}{\sum_{j=1}^{J} \text{Exports}_{kj}} \tag{5}$$

Country k's neighbor set $B_k(n)$ consists of its n largest export markets, i.e., the n countries with highest $BT_{kk'}$. The cross-country effects are then operationalized as:

$$q^B_{kk'} = \begin{cases} \lambda^B_k & \text{if} \quad k' = k \\ \gamma^B_k & \text{if} \quad k' \in B_k(n) \\ 0 & \quad\text{otherwise} \end{cases} \tag{6}$$

Again, n is specified empirically. Note that this definition of neighbor sets is not symmetric: for instance, the US is a key export market for many countries, many of which are not major export markets for the US.

Cultural dimensions The third definition of cross-country influence is based on cultural similarity. To numerically represent the culture of a given country, we use Hofstede's (2001) four cultural dimensions: (1) power distance, (2) individualism, (3) masculinity, and (4) uncertainty avoidance.[7] In his seminal cross-cultural research, Hofstede (2001) determined the "coordinates" of each country on these four dimensions. These cultural dimensions have been used in other work on comparing innovativeness at firms across countries. For instance, Shane (1993) finds a link between

[6] We also tested a countinuous distance specification, with $q_{kk'} = \exp\left(-\gamma_k D^{-1}_{kk'}\right)$, where $D_{kk'}$ is the geographical distance between country k and k'. This specification produced worse results in terms of fit.

[7] These dimensions mean the following: (1) "Power Distance" focuses on the degree of equality vs. inequality between different people, in terms of power and wealth; (2) "Individualism" focuses on the importance given to the individual vs. the collective, in terms of achievements and relationships; (3) "Masculinity" deals with the traditional role played by the man in terms of control, power and achievement; (4) "Uncertainty Avoidance" regards the level of tolerance for uncertainty and risk.

culture and the number of trademarks per country, while Van Everdingen and Waarts (2003) find that culture affects country-level adoption rates of enterprise resource planning (ERP) systems. In our model, each country k is represented by four scores sc_{ks}, with $s = 1, ..., 4$, one for each of Hofstede's dimensions. We define the cultural distance between countries k and k' using the distance measure

$$H_{kk'} = \sqrt{\sum_{s=1}^{4} (sc_{ks} - sc_{k's})^2} \tag{7}$$

For each country k, the set $H_k(n)$ of neighbors consists of the culturally closest n countries to country k. The cross-country effects are operationalized as:

$$q^H_{kk'} = \begin{cases} \lambda^H_k & \text{if} \quad k' = k \\ \gamma^H_k & \text{if} \quad k' \in H_k(n) \\ 0 & \quad\quad \text{otherwise} \end{cases}, \tag{8}$$

with n determined experimentally.

Combining the neighborsets Finally, a general neighbor set can be defined as any subset of the three previous definitions, e.g., the union:

$$q^A_{kk'} = \begin{cases} \lambda^A_k & \text{if } k' = k \\ q^G_{kk'} + q^B_{kk'} + q^H_{kk'} & \text{if } k' \neq k \end{cases} \tag{9}$$

where $q^G_{kk'}$, $q^B_{kk'}$, and $q^H_{kk'}$ are as defined previously in equations (4), (6), and (8). These cross-country effects contain the parameters γ^G_k, γ^B_k, and γ^H_k, which are estimated concurrently. Identification of the γ's follows from the observation that for any given n, the sets $G_k(n)$, $B_k(n)$ and $H_k(n)$ are not identical. Under the union of these sets, each country k may thus have more than n neighbors.

An example: India The countries in our sample that are considered India's neighbors, assuming $n = 5$, under each of the above definitions are:

- geographical distance: Pakistan, United Arab Emirates, Iran, Thailand, Saudi Arabia
- bilateral trade: USA, Japan, United Kingdom, Hong Kong, United Arab Emirates
- cultural: Egypt, Jordan, Saudi Arabia, United Arab Emirates, Kenya
- combined: the union of all 12 countries listed above.

The countries are listed in order of proximity under each measure; it is clear that the neighbor set and ordering of neighbors varies substantially across the different measures.

3.4 Country heterogeneity

We use two alternative methods to account for heterogeneity in the country diffusion rates. The first method uses country-specific covariates to account for heterogeneity in diffusion rates (see e.g. Gatignon et al. 1989; Putsis et al. 1997). Specifically, we make the parameters p_k, M_k, λ_k and γ_k a linear function of country characteristics, $\mathbf{x}_k$:

$$\begin{aligned} M_k &= \mathbf{x}_{Mk}\boldsymbol{\beta}_M && (10) \\ p_k &= \mathbf{x}_{pk}\boldsymbol{\beta}_p && (11) \\ \lambda_k &= \mathbf{x}_{\lambda k}\boldsymbol{\beta}_\lambda && (12) \\ \gamma_k &= \mathbf{x}_{\gamma k}\boldsymbol{\beta}_\gamma && (13) \end{aligned}$$

where $\mathbf{x}_{pk}$, $\mathbf{x}_{Mk}$, $\mathbf{x}_{\lambda k}$ and $\mathbf{x}_{\gamma k}$ are country-specific covariates such as population, urbanization, and illiteracy ratings, for each parameter. These expressions can be substituted in equation (1) to get a fixed effects model of country heterogeneity. The resulting model captures observed heterogeneity across countries.

An alternative approach accounts for unobserved as well as observed differences across countries through a random coefficients model (e.g., Talukdar et al. 2002), where a hierarchical structure is placed on the parameters. Including cross-country effects, each parameter has a distribution of the following form:

$$\begin{aligned} M_k &\backsim N\left(\mathbf{x}_{Mk}\boldsymbol{\beta}_M, \sigma_M^2\right) && (14) \\ p_k &\backsim N\left(\mathbf{x}_{pk}\boldsymbol{\beta}_p, \sigma_p^2\right) && (15) \\ \lambda_k &\backsim N\left(\mathbf{x}_{\lambda k}\boldsymbol{\beta}_\lambda, \sigma_\lambda^2\right) && (16) \\ \gamma_k &\backsim N\left(\mathbf{x}_{\gamma k}\boldsymbol{\beta}_\gamma, \sigma_p^2\right) && (17) \end{aligned}$$

The first model produces a distribution for the parameter vectors $\beta = [\beta_p;\ \beta_M;\ \beta_\lambda;\ \beta_\gamma]$. The country-specific parameter values for each country then result from equations (10) to (13). The second model provides distributions of the final parameters M_k, p_k, λ_k and γ_k *for each country*, capturing heterogeneity more flexibly.

The covariates used in this study are as follows. For the potential number of certifications M_k, we choose population and GDP per capita as the main source of heterogeneity. Larger and more populated countries have a larger base of firms that may adopt the ISO 9000 standard. Firms in developed countries, with higher GDP per capita, are likely to be more able to support the costs of obtaining ISO 9000 certification than firms in developing countries. Specifically for ISO 14000, we include the sum of the “social and institutional capacity” and “global stewardship” components of the environmental sustainability index (World Economic Forum, 2002), as a covariate. (This measure consists of 35 variables, making it much broader than the measure based on number of environmental treaties used in earlier work.)

In terms of both the coefficient of innovation p_k and contagion effects λ_k and γ_k, access to sources of information such as the ISONET or the ISO catalogues and the ability to transmit and process information included in those sources is necessary for the adoption process. Consequently, we use the literacy rate in each country as a covariate. Also, studies in urban economics (Calem and Carlino, 1991) show that urban centers offer better infrastructure and consequently facilitate faster diffusion of information about adoption of ISO 9000, so we also include percentage of urban population. Empirically, variable selection for each model in (10) – (17) is based on model likelihood (corrected for overfitting) and prediction.

3.5 Omitted variables

A final feature of our model is that it allows for contemporaneous correlation in the residuals e_{kt} across countries. This helps control for those omitted variables that cause a simultaneity in certification across countries. Examples of such simultaneities are local business cycles with highs and lows that are common to a neighbor set of countries, or firms exerting influence on firms in other countries as soon as they start the certification process.

A parsimonious model of contemporaneous correlation can be specified as a spatial correlation on the residuals of equation (1). Recall that these residuals are heteroskedastic with variance $c_{kt-1} \cdot \sigma_e^2$. For ease of notation, define the transformed residuals $\widetilde{e}_{kt} = e_{kt}/\sqrt{c_{kt-1}}$. Instead of assuming that the error component $\widetilde{e}_{kt}$ is independent across countries, we allow for a more general autocorrelated error process on the $[K \times 1]$ error vector $\widetilde{\mathbf{e}}_t$. That is,

$$\widetilde{\mathbf{e}}_t = \mu \mathbf{W} \widetilde{\mathbf{e}}_t + \boldsymbol{\eta}_t \tag{18}$$

where $\mathbf{W}$ is a $K \times K$ matrix whose rows $\mathbf{W}_k$ consist of elements with the value $1/n$ for all $k' \in G_k(n)$ and 0 otherwise. The interpretation of equation (18) is that $\tilde{e}_{kt}$ is allowed to be a function of the average $\tilde{e}_{k't}$ in the spatial neighbor set. In this equation, μ has the interpretation of a spatial autoregressive coefficient and the non-spatial structure component η_{kt} is distributed as $\eta_{kt} \sim N\left(0, \sigma_\eta^2\right)$.[8]

[8] Anselin (1981) shows that the joint distribution of the spatial error vector $\tilde{\mathbf{e}}_t$ is normal with mean 0 and variance-covariance matrix equal to $\sigma_\eta^2 \left(\left(\mathbf{I} - \mu \mathbf{W}' \right) \left(\mathbf{I} - \mu \mathbf{W} \right) \right)^{-1}$

To summarize, we have presented a model of diffusion of ISO 9000 (and ISO 14000) certification that (1) accounts for cross-country effects and own-country effects, (2) operationalizes different definitions of cross-country effects, (3) allows for observed and unobserved differences across countries, and (4) accounts for omitted variables with a spatial structure. This model is of course very general. It can be estimated on country by year panel data of certification counts.

4 Data

Our data for the number of ISO 9000 and ISO 14000 certifications issued were obtained from ISO, which took over the original Mobil survey of global certification data that was started in 1992. Altogether, 12 "cycles" of the global certification survey have been released during 1992-2003 (ISO 2003). Though the survey has been annual since 1995, the earliest cycles were released at irregular intervals. To transform the early data to an annual grid, we used cubic spline interpolation between sample points.[9] In the year 2000, a major revision of the ISO 9000 standard was released, ISO 9000:2000. It appears that significant numbers of firms that were previously certified to the earlier version of the standard did not seek re-certification to the new version, although re-certification is required every three years to keep the certification current. Other firms have consolidated multiple site-level certifications into a single global firm-level certification, which was not possible under the earlier versions of the standard. Regardless, because neither disadoption nor consolidation is the focus of our study, we discarded the data on ISO 9000 certification after 2000 (in this case for the years 2001 and 2002). This leaves 9 annual observations per country (1992-2000) for ISO 9000. ISO 14000 was published in September 1996, and did not undergo any major revision. We have 8 annual observations for 1995-2002 (some firms received certification before the final standard was published).

The initial sample includes all countries which have at least one ISO 9000 certification by the year 2002, in total 169 countries. It is impossible to meaningfully estimate diffusion patterns in countries with severely limited data so we restrict our analysis to countries with at least 200 cumulative certifications. This left a sample of 59 countries. We lack information about bilateral trade or country characteristics for three of these countries (Taiwan, Lithuania and Latvia) as a result of inconsistent treatment of these countries across different databases. Consequently, our final sample includes 56 countries. For consistency, the same sample was used for ISO 14000. Figure 1 gives a graphical impression of the spatial sample.

[9] For a discussion of the estimation of the Bass model in the context of irregular time units see Radas and Shugan (1998).

———— Insert Figure 1 here.————

Of the 56 countries, 31 had less than 20 ISO 9000 certifications in 1993, which means that in most countries widespread adoption had not yet started. In contrast, for the last year included in the analysis ($T = 2000$ for ISO 9000, $T = 2002$ for ISO 14000), the mean cumulative number of ISO 9000 and ISO 14000 certifications respectively is 7,170 and 851, with a standard deviation of 11,664 and 1,622. Figure 2 shows that the diffusion curves of selected countries are either S-shaped or convex. These patterns are consistent with the outcome of a diffusion process and generalize to the other countries.

———— Insert Figure 2 here.————

Additional country data were collected from various sources. Economic and demographic information about each country was obtained from the TableBase database (Dialog, 2003), from the CIA World Factbook (CIA, 2003) and from the Census Bureau. The covariates used in the models are for 1997, with the exception of population, which is for the year 2000. Bilateral trade data from 1996 were collected from the World Trade Flows, 1980-1997 (Feenstra, 2000). To make the covariates of consistent scale, they were standardized prior to using them in the diffusion model. Geographic distance between countries was calculated using the latitude and longitude of the country's capital, representing the shortest surface distance between the two points. The cultural data were taken from Hofstede (2001). In these data, the Arab countries in our sample (Egypt, Jordan, Saudi Arabia and UAE) have the same values for the different cultural dimensions. For Cyprus, we used Greece's cultural scores; for Kenya, we applied the scores for Eastern Africa.

5 Empirical analysis

5.1 Estimation

We use Bayesian methods to obtain estimates for each parameter's mean and standard deviation. Bayesian methods allow us to estimate all proposed models, from fixed effects to hierarchical random coefficients, within a consistent framework. Our time series are short: for ISO 9000 (ISO 14000) we have only 9 (8) observations per country. Given that the model focuses on annual differences in certification rather than levels, we "lose" one observation. Another observation is needed for initialization of the model in equation (3). Finally, we use the last available observation (year 2000 for ISO 9000; year 2002 for ISO 14000) as a holdout in order to evaluate prediction. This leaves us with 6 observations per country for model estimation in the case of ISO 9000 and 5 in the case of ISO 14000.[10] Such short time series are not uncommon when studying adoption outcomes that are collected at a low frequency, as is the case with ISO 9000 and ISO 14000 certification. The use of Bayesian methods in this case allows us to make the most of the country-specific data to estimate country diffusion rates. However, for those countries where the within-country data are uninformative of the diffusion process, the method will "shrink" the estimates toward the global mean. The amount of shrinkage is determined by the informativeness of the within-country data relative to the pooled across-country data.

Using Markov Chain Monte Carlo (MCMC) methods, we sample from the marginal posterior distribution of each parameter in turn, conditional on the current values of other parameters and on the data (Tanner and Wong, 1989; Gelfand and Smith, 1990).[11] All models were run for a total of 20,000 iterations. The first 15,000 observations were used for initialization purposes and the last 5,000 iterations were used for inference. Specifically, to reduce the autocorrelation in the MCMC sampler, every fifth draw was saved for analysis. Convergence of the parameter values was confirmed by examining the plots of the sampled values for each parameter. We also tested for differences in parameters' means across different intervals (Gelman, Carlin, Stern and Rubin, 1995) and found none significant. In most cases, convergence was achieved after 3,000 to 4,000 iterations.

We carried out preliminary tests with different values for neighbor set size n for each distance measure. The best results in terms of fit and prediction were obtained with a small set of neighbors, between 3 and 8, with little sensitivity within that range. In order to make the different cross-country contagion mechanisms comparable and to keep the number of empirical models manageable, we opted to run all models with $n = 5$.

Recall that in addition to the 32 models defined in the modeling section, we defined 4 variants of the baseline model without cross-country effects depending on whether we account for unobserved heterogeneity (yes/no) and for omitted variables (yes/no). Our model selection strategy for the ISO 9000 and ISO 14000 data sets is to estimate and compare all 32 models with cross-country effects and all four models without cross-country effects, i.e., 36 models for each standard.

Figure 3 shows the actual number of ISO 9000 certifications for two multi-country cross-sections ($T = 1997, 2000$), compared to the fitted ($T = 1997$) and the predicted ($T = 2000$) values obtained from the model specification with geographic cross-country effects, random effects to account for cross-country heterogeneity, and no contemporaneous correlations in errors. As the figure shows, the

[10]In several countries the number of observations is further reduced by the certification process starting late, i.e., we do not use observations in a particular country until at least one certification has been recorded.

[11]A detailed appendix of the MCMC estimation algorithm is included separately with this paper.

model is generally very effective in tracking the cross-country heterogeneity in ISO 9000 certification.

——— Insert Figure 3 about here.———

5.2 Model selection

In order to focus our discussion on cross-country effects, we first make a rough selection among the many specifications by comparing them empirically, using the criteria of marginal likelihood and root of the mean squared error (RMSE). For each model, we calculate the marginal likelihood as the harmonic mean of the posterior likelihood values across iterations of the sampler (Newton and Raftery, 1994; Gelfand and Dey, 1994). The marginal likelihood warrants against overfitting the data. This is because overfitting increases the variability of the likelihood across iterations which in turn diminishes the harmonic mean of the likelihoods (i.e. the marginal likelihood). As a result, models that include more parameters, such as the "combined" specification, may present worse marginal likelihood values. The RMSE statistics are estimated from the differences between the predicted vs. the actual certification for the holdout period in the data (2000 for ISO 9000, 2002 for ISO 14000) at every sweep of the sampler.[12]

Table 1 shows the log of marginal likelihoods for the 36 model specifications for both the ISO 9000 and the ISO 14000 data. The table shows that, in most cases, the models with long-term (cumulative) cross-country influence provide a better fit than those with short-term influence. In addition, Table 2 shows the prediction performance for the same 36 models. According to this table the maximum prediction accuracy using the long-term (cumulative) cross-country influence is slightly better or similar to that using the short-term model. Given the superior fit and the (mostly) better prediction results, we retain for further analysis those specifications that use cumulative certifications as the relevant contagion variables.

——— Insert Tables 1 and 2 about here.———

Contrasting the random-coefficients models that account for unobserved heterogeneity with the fixed-effects specifications that do not, we see that the former fit better and produce substantially better predictions of ISO 9000 and ISO 14000 certifications than the latter. This is an important benefit of our Bayesian estimation approach. Given the small number of observations in the time series, it is difficult to meaningfully account for country-specific diffusion parameters using classical methods. However, our results show that the information in the time series helps make much

[12]Consistent with equation 2, these differences are scaled by $c_{k,t-1}$. This scaling of the differences prevents model selection from being dominated by one or two countries with the largest number of certifications.

better predictions. In view of the presented fit and prediction accuracy, we carry forward the model specifications that account for unobserved country heterogeneity through random effects.

We also observe from the tables that there is limited support for the models with contemporaneously correlated errors to account for omitted variables. This is especially true for the random coefficients models. Hence, after accounting for unobserved heterogeneity, there appears to be little evidence for contemporaneous correlation in the residuals across countries. Given that the model without such effects is more parsimonious, we retain these for further analysis.

We now turn to an in-depth analysis of cross-country effects on a selective subset of the 36 models. From the discussion above, the selected models have in common that they (1) are based on cumulative certification rates in other countries, (2) account for unobserved heterogeneity, and (3) have independent errors across geography. This subset consists of the best specifications in terms of fit and prediction, or when there is no systematic difference in performance, the specifications that are more parsimonious. The substantive conclusions of our paper do also apply outside this set.

6 Cross-country diffusion

6.1 Mechanisms of cross-country influence

The fit and prediction statistics in Tables 1 and 2 show that the specifications without cross-country effects fit and usually predict worse for ISO 9000 certification and ISO 14000 certification. The empirical evidence therefore clearly points to the presence of cross-country effects in the spread of both standards.

For ISO 9000, the cross-country effects based on geographic distance produce superior fit and good prediction. The cross-country effects defined by strong bilateral trade dependencies provide good fit and superior prediction. However, the cross-country effect defined by cultural similarity performs the worst in terms of fit and especially prediction. Thus, the data suggest that the cross-country contagion in ISO 9000 certification follows patterns of geography and export relations rather than cultural similarity.

The strong impact of geographic distance suggests that firms in neighboring countries have a greater tendency (perhaps because they have more opportunity) to observe and share information about management practices. To the extent that this leads to competitive mimicry (Guler et al., 2002), the geographic effect may be seen as “horizontal” information sharing (i.e., involving similar firms). The strength of the bilateral trade link is likely the result of firms requiring their suppliers to have ISO 9000 certification, regardless of their location. This contagion process is among buyer-seller diads and can therefore be termed "vertical." Our findings suggest that both types of contagion contribute to global diffusion of ISO 9000 certification.

In contrast, for the ISO 14000 data, the cultural distance specification produces good fit and superior prediction. The bilateral trade specification fits well but produces worse fit. The geographic specification fits the worst. Comparing the two data sets, the role of cultural similarity in cross-country contagion therefore appears larger for ISO 14000 than for ISO 9000 certification. Though tentative, this finding is consistent with the fact that ISO 14000 involves a broader set of stakeholders, involving communities and authorities than ISO 9000 does. These additional stakeholders reflect a country's cultural characteristics more strongly than the narrower set of stakeholders involved in ISO 9000 certification.

In sum, the diffusion models presented here are capable of identifying different mechanisms in the spread of ISO 9000 and ISO 14000 certification. An important difference between the two standards is that ISO 9000 certification has a stronger geographic component, while ISO 14000 spreads more to culturally similar countries. In addition, our results confirm the importance of trade relations in the spread of both standards.

6.2 The diffusion parameters

As mentioned before, in the specifications (14) to (17), the country-specific effects M_k, p_k, λ_k and γ_k are modeled as functions of underlying covariates. To prevent overfitting, we base the inclusion of covariates on marginal likelihood improvements. Tests with the fixed effects models revealed that the coefficients of GDP per capita and (in the case of ISO 14000) the environmental sustainability index (ESI) were insignificant. These variables were suppressed from subsequent analysis. While the insignificance of the ESI seems at odds with the study by Neumayer and Perkins (2004), (1) we analyse a different dependent variable than they do (the growth in annual certifications versus the annual certification levels), and (2) their results indicate that "attitude to the environment" is only weakly significant. We found that in the presence of country-specific random effects, the ESI variable becomes insignificant.

In the case of the random coefficients specification, testing showed that the only significant covariate was population (for M_k). This is not surprising. The random effects model accounts for country-level effects which in turn absorb the explanatory power of other variables at the country level.

——— Insert Table 3 about here.———

Table 3 reports parameter estimates for selected random effects models for both data sets. The potential number of certifications M_k in country k is positively related to population size. The innovation coefficient is around 0.04 for ISO 9000 and around 0.05 for ISO 14000. These values are consistent with, yet slightly higher than, those found in meta-analyses on diffusion parameters for durable and high technology consumer products. For instance Sultan, Farley, and Lehmann (1990) find an average value for p of 0.03. The slightly higher innovation coefficient means that the diffusion process for management standards has a larger autonomous component than that for a typical durable consumer good.

Turning to the within-country imitation coefficients, when cross-country imitation is accounted for, the own-country imitation coefficients are $0.22-0.31$ and $0.26-0.38$ for ISO 9000 and ISO 14000 respectively. Sultan et al. (1990) find an average value of 0.3 for the imitation effect in the diffusion of consumer durable products. Note that the own-country imitation coefficient is inflated by 50% to 100% when cross-country imitation is not accounted for. This suggests that any work on multi-country diffusion that does not explicitly consider the cross-country influence may confound within- and cross-country imitation effects and hence overestimate the within-country imitation parameter. This is particularly true for international management standards such as ISO 9000 and ISO 14000, where there are good reasons to expect that firms in different countries influence each other's certification decisions.

In Table 3, the estimated cross-country effect coefficients vary from 0.040 to 0.181. They are higher for ISO 14000 than for ISO 9000 certification as is also true for the innovation coefficients and the own-country imitation coefficients. This suggests that ISO 14000 certification diffuses more rapidly than ISO 9000, which may reflect that the learning that occurred with ISO 9000 facilitated adoption of ISO 14000. For both data sets, we observe considerable heterogeneity across countries, i.e., some countries are more prone to external influence than others. Developed countries show larger cross-country effects, while developing countries are more isolated. This suggests that developing countries will lag in the adoption of management standards, while firms in developed countries appear to be a part of a global network, for instance through partnerships and alliances, that provides the necessary incentives to adopt ISO 9000 and ISO 14000. A deeper analysis of this finding is described in the next section.

A final discussion point involving the parameter estimates concerns the ability of our model to capture multiple diffusion effects. To illustrate this we plot, in Figure 4, the contribution over time of each diffusion effect for the best overall random effects diffusion model with the ISO 9000 data, i.e., that with a combination of geographical and bilateral trade cross-country effects. The figure presents the estimated annual number of *new* certifications for ISO 9000 resulting from innovation effects, own-country effects and the two types of cross-country imitation effects for four countries: Canada, India, China and Spain.

——— Insert Figure 4 here.———

It is interesting to note that Canada consistently shows a higher dependence on cross-country effects resulting from bilateral trade, while China shows more regionalized dependence. India and Spain, on the other hand, show a shift in cross-country effects through time. In the initial two years, innovation and bilateral trade are the driving forces behind the diffusion process for both countries. Subsequently in India, geographic neighbor imitation becomes more important, while within-country imitation takes over in Spain. A clear conclusion from these examples is that the impact of the different effects (innovation, within-country and cross-country imitation) varies substantially across countries *and* time and that our model can account for these patterns. This is important because if the dominant diffusion mechanism changes, different incentives may be necessary to promote the adoption of management standards at different stages of the diffusion process.

7 Cross-country influence and susceptibility

The empirical results suggest that the diffusion of ISO 9000 and ISO 14000 certification takes place within a global network of firms and managers, organized by geography, trade, and/or culture. In this section, we use our model to propose two empirical measures of the importance of countries in stimulating certification across borders and we illustrate it with the ISO 9000 data. These measures, influence and susceptibility, seek to represent how much a country contributes to foreign certification and how much foreign countries contribute to domestic certification, respectively. They are computed from the estimated cross-country influence matrix $q_{kj}, \{k, j = 1, ..., K\}$ (for further discussion in a similar context see Wasserman and Faust 1994). The influence index I_{kt} is defined as the summed fraction of certifications that county k causes in other countries

$$I_{kt} = \sum_{j=1,...,K;j\neq k} \underbrace{q_{jk} \cdot \frac{C_{k,t-1}}{M_k}}_{\text{pressure of } k \text{ on } j} \cdot \underbrace{\frac{(M_j - C_{j,t-1})}{M_j}}_{\text{untapped share in } j} . \tag{19}$$

The index I_{kt} combines two terms. The first term is simply the multiplication of the coefficient q_{jk}, that captures the strength of influence of k on j, with the cumulative certification base $\frac{C_{k,t-1}}{M_k}$ in k. This term serves as a measure of the "pressure" exerted by country k on j. The second term is the "untapped" share of firms in country j.

Similarly the susceptibility of country k is equal to

$$S_{kt} = \sum_{j=1,\ldots,K;j\neq k} \underbrace{q_{kj} \cdot \frac{C_{j,t-1}}{M_j}}_{\text{pressure of } j \text{ on } k} \cdot \underbrace{\frac{(M_k - C_{k,t-1})}{M_k}}_{\text{untapped share in } k} . \tag{20}$$

This measure equals the share of potential domestic certification in country k and year t that the model attributes to foreign pressures. Figure 5 presents the summed (across time) measures of influence, $\sum_t^T I_{kt}$, and susceptibility, $\sum_t^T S_{kt}$, using the combined specification (5) for ISO 9000 in Table 3. Note that the cumulative susceptibility index $\sum_t^T S_{kt}$ is equal to the total share of certifications in k due to foreign pressures from $j \neq k$ (see equation 1). That is, each term S_{kt} is equal to the predicted "foreign driven" share of potential certifications M_k in period t. Because many countries are clustered in the low regions of influence, we use a log transform of influence, $\log(\sum_t I_{kt})$, in Figure 5 to avoid cluttering.

——— Insert Figure 5 here.———

From the figure it is clear that countries like the UK, Japan, the USA, etc., appear to have low susceptibility to cross-national diffusion coupled with a large influence on other countries. That is, consistent with intuition, the model estimates that for firms in these countries certification is not driven by firms in other countries, but rather by those at home. Within the confines of the model, these countries owe their influence to their central place in the bilateral trade matrix and/or geography. On the other side of the spectrum reside countries like Thailand and Korea that have little influence but are quite susceptible. Surprising is the large concentration of countries that are prone to foreign influence. Indeed, the susceptibility index is larger than 0.5 in many countries. For these countries, the majority of domestic ISO 9000 certification originates from cross-country influence. For policy makers interested in encouraging rapid diffusion of management practices, our results suggest that focusing on gaining rapid acceptance in a few key influential countries helps accelerate adoption in many other, more susceptible, countries.

8 Conclusion

We presented a model of international diffusion of management standards and estimated it on country by year data on ISO 9000 and ISO 14000 certification. Our diffusion model is based on the well-known Bass (1969) model and adds several new elements to it: cross-country dependence, unobserved country differences, and omitted variable correction. We believe the class of diffusion models presented here offers advantages in measuring the spread of certifications above and beyond the cross-sectional or panel data models which have been used before.

The paper provides a structured empirical comparison of alternative diffusion model specifications intended to account for a wide array of country-specific features and cross-country influences. An in-depth analysis of the best model specifications revealed that cross-country effects are statistically (see Table 3) and substantively (see Figure 5) important in both ISO 9000 and ISO 14000 certification. Our findings are further informative of the specific nature of the cross-country influence for ISO 9000 and ISO 14000 certification. ISO 9000 certification follows export flows and geographic proximity while ISO 14000 certification appears to also diffuse across culturally similar countries.

The diffusion parameters estimated for each data set are fully consistent and strikingly close to the values for these parameters obtained from meta analyses in the diffusion literature (e.g., Sultan et al. 1990). In turn, this supports the use of diffusion models in the context of the adoption of management practices. This paper constitutes the first application of a diffusion model in the literature on ISO 9000 or ISO 14000 to do so.

The flexibility of our model allows the nature of diffusion to be specific to a particular country. In effect, the results of our estimations show that significant differences in diffusion rates exist and that the nature of diffusion differs across countries and across time. Finally, we used the estimation results to compute measures of influence and susceptibility in the spread of ISO 9000 and found that most countries are strongly susceptible to the influence of certification levels in a few other countries. Applied to similar future standards or to diffusion of other technologies, our model can help determine the identity of these countries to target for early adoption in order to achieve faster global diffusion.

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ISO 9000	Fixed Effects Models No omitted var.	Fixed Effects Models Omitted var.	Random Coefficients Models No omitted var.	Random Coefficients Models Omitted var.
No cross-country effects	-1695.3	-1689.7	-1584.4	-1584.3
Cross-country effects				
Short-term: geography	-1685.5	-1682.6	-1536.2	-1540.1
Short-term: bilateral trade	-1695.4	-1689.9	-1546.5	-1550.2
Short-tem: culture	-1688.2	-1679.0	-1561.2	-1531.1
Short term: combined	-1721.4	-1682.8	-1553.9	-1586.9
Long-term: geography	-1683.2	-1676.9	-1513.9[a]	-1516.9
Long-term: bilateral trade	-1693.5	-1689.3	-1522.6	-1528.4
Long-term: culture	-1680.5	-1687.0	-1524.8	-1565.6
Long-term: combined	-1734.8	-1689.5	-1520.5	-1574.0
ISO 14000				
No cross-country effects	-1183.1	-1182.2	-1048.7	-1047.9
Cross-country effects				
Short-term: geography	-1185.2	-1184.8	-1024.0	-1018.3
Short-term: bilateral trade	-1184.8	-1183.6	-1015.3	-1015.2
Short-tem: culture	-1185.5	-1183.6	-1020.8	-1017.8
Short term: combined	-1189.0	-1188.3	-1008.3	-1039.6
Long-term: geography	-1181.2	-1183.4	-1014.7	-1018.2
Long-term: bilateral trade	-1182.5	-1181.5	-998.2	-997.2
Long-term: culture	-1184.9	-1195.6	-999.1	-997.0
Long-term: combined	-1197.1	-1190.9	-998.7	-1032.0

[a]The underlined statistics correspond to the models selected for further analysis.

Table 1: Log Marginal Likelihoods for all model specifications in the ISO 9000 and ISO 14000 data sets.

ISO 9000	Fixed Effects Models No omitted var.	 Omitted var.	Random Coefficients Models No omitted var.	 Omitted var.
No cross-country effects	68.88	65.87	<u>60.01</u>	59.14
Cross-country effects				
Short-term: geography	72.59	72.39	56.51	55.80
Short-term: bilateral trade	68.39	65.84	56.66	56.09
Short-tem: culture	64.84	74.41	60.47	66.16
Short term: combined	65.70	65.38	56.26	55.68
Long-term: geography	79.51	78.80	<u>56.57</u>[a]	57.26
Long-term: bilateral trade	68.01	66.63	<u>54.75</u>	55.90
Long-term: culture	70.14	67.04	<u>66.05</u>	61.03
Long-term: combined	69.62	67.21	<u>55.96</u>	57.99
ISO 14000				
No cross-country effects	25.4	26.1	<u>21.7</u>	21.3
Cross-country effects				
Short-term: geography	24.4	25.1	21.3	20.4
Short-term: bilateral trade	25.3	26.3	21.8	21.4
Short-tem: culture	24.6	25.7	21.8	22.2
Short term: combined	29.1	24.6	21.7	22.5
Long-term: geography	26.8	26.3	<u>21.5</u>	22.7
Long-term: bilateral trade	25.7	26.5	<u>22.1</u>	22.6
Long-term: culture	24.9	30.2	<u>19.4</u>	19.8
Long-term: combined	30.6	29.4	<u>23.0</u>	29.2

[a]The underlined statistics correspond to the models selected for further analysis.

Table 2: Mean Squared Errors for holdout predictions across all model specifications in the ISO 9000 and ISO 14000 data sets.

ISO 9000	(1)	(2)	(3)	(4)	(5)	(6)
Market potential: intercept/1000	3.670	5.198	3.998	9.452	8.009	7.481
	(3.630)	(2.426)	(2.731)	(1.680)	(1.625)	(1.629)
Market potential: population	4.765	1.888	2.492	3.152	2.052	1.877
	(2.160)	(0.940)	(1.109)	(1.284)	(1.003)	(0.899)
Innovation coefficient	0.043	0.042	0.044	0.045	0.044	0.042
	(0.028)	(0.027)	(0.028)	(0.027)	(0.027)	(0.027)
Imitation coefficient						
Own-country	0.478	0.278	0.306	0.291	0.246	0.218
	(0.067)	(0.052)	(0.055)	(0.051)	(0.046)	(0.043)
Cross-country: geography		0.095			0.076	0.059
		(0.030)			(0.029)	(0.027)
Cross-country: bilateral trade			0.061		0.047	0.040
			(0.027)		(0.027)	(0.026)
Cross-country: culture				0.105		0.066
				(0.034)		(0.029)
Error variance	722.1	456.5	477.3	489.3	436.5	427.66
	(64.0)	(40.1)	(41.5)	(43.8)	(39.3)	(39.5)
ISO 14000	(1)	(2)	(3)	(4)	(5)	(6)
Market potential: intercept/1000	1.747	1.301	1.136	1.322	1.044	0.923
	(0.399)	(0.244)	(0.238)	(0.244)	(0.214)	(0.212)
Market potential: population	0.549	0.235	0.262	0.372	0.221	0.198
	(0.405)	(0.165)	(0.148)	(0.176)	(0.113)	(0.108)
Innovation coefficient	0.040	0.045	0.065	0.046	0.055	0.064
	(0.027)	(0.028)	(0.030)	(0.028)	(0.028)	(0.027)
Imitation coefficient						
Own-country	0.799	0.370	0.379	0.342	0.282	0.260
	(0.099)	(0.063)	(0.070)	(0.058)	(0.053)	(0.049)
Cross-country: geography		0.181			0.098	0.085
		(0.033)			(0.031)	(0.031)
Cross-country: bilateral trade			0.118			0.090
			(0.033)			(0.031)
Cross-country: culture				0.133	0.108	0.098
				(0.035)	(0.032)	(0.032)
Error variance	100.75	75.91	67.85	69.22	65.43	62.31
	(9.75)	(7.37)	(7.02)	(7.33)	(7.40)	(6.12)

Table 3: Parameter estimates for the ISO 9000 and ISO 14000 data sets with standard deviations in parentheses: Model (1) has no cross-country effects. Model (2) – Model (4) contain cross-country effects based on geography, bilateral trade and culture, respectively. Model (5) combines the best fitting two versions of cross-country effects from Model (2) – Model (4). Model (6) combines all definitions of cross-country effects

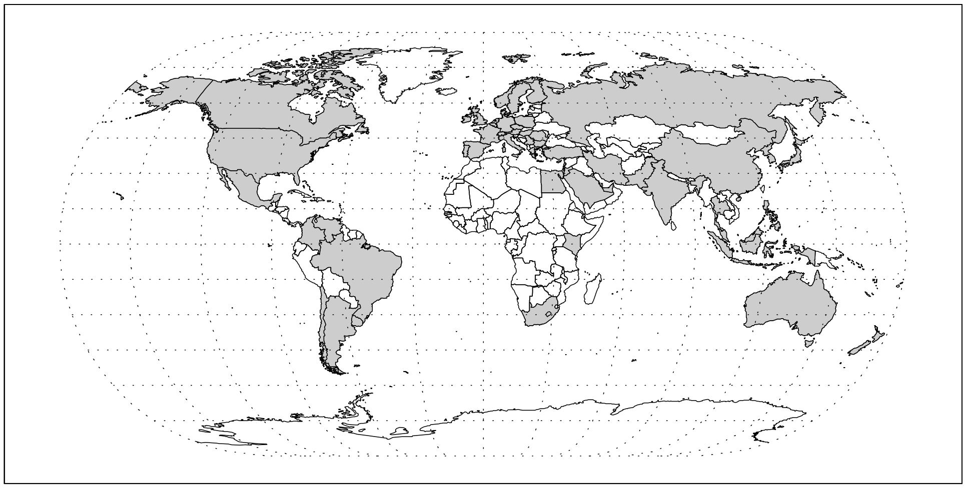

Figure 1: Map of the spatial sample

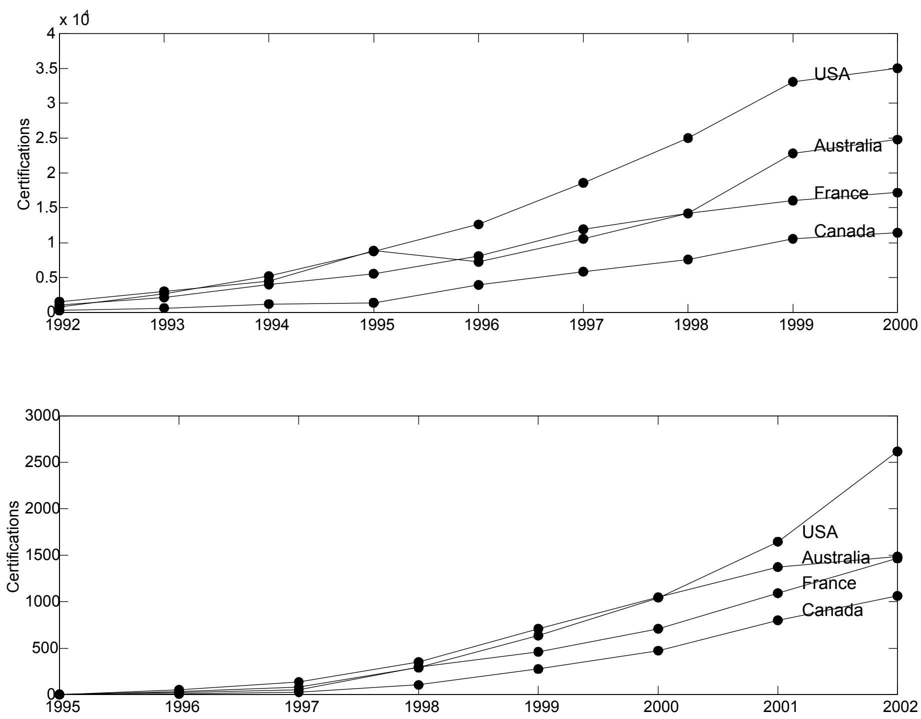

Figure 2: Yearly ISO 9000 and ISO 14000 certification counts for 4 countries.

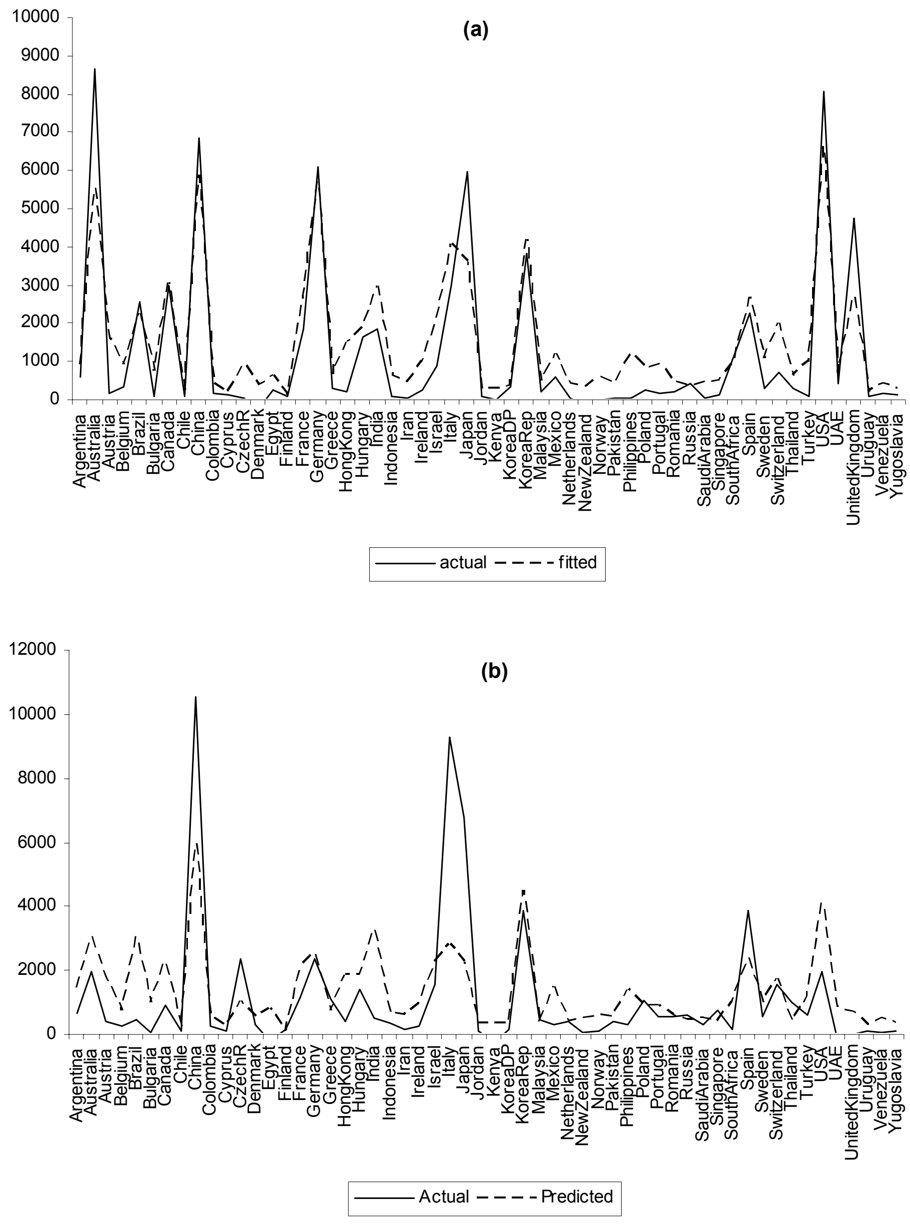

Figure 3: (a) actual and fitted new ISO 9000 certifications for 1997, (b) actual and predicted new ISO 9000 certifications for 2000

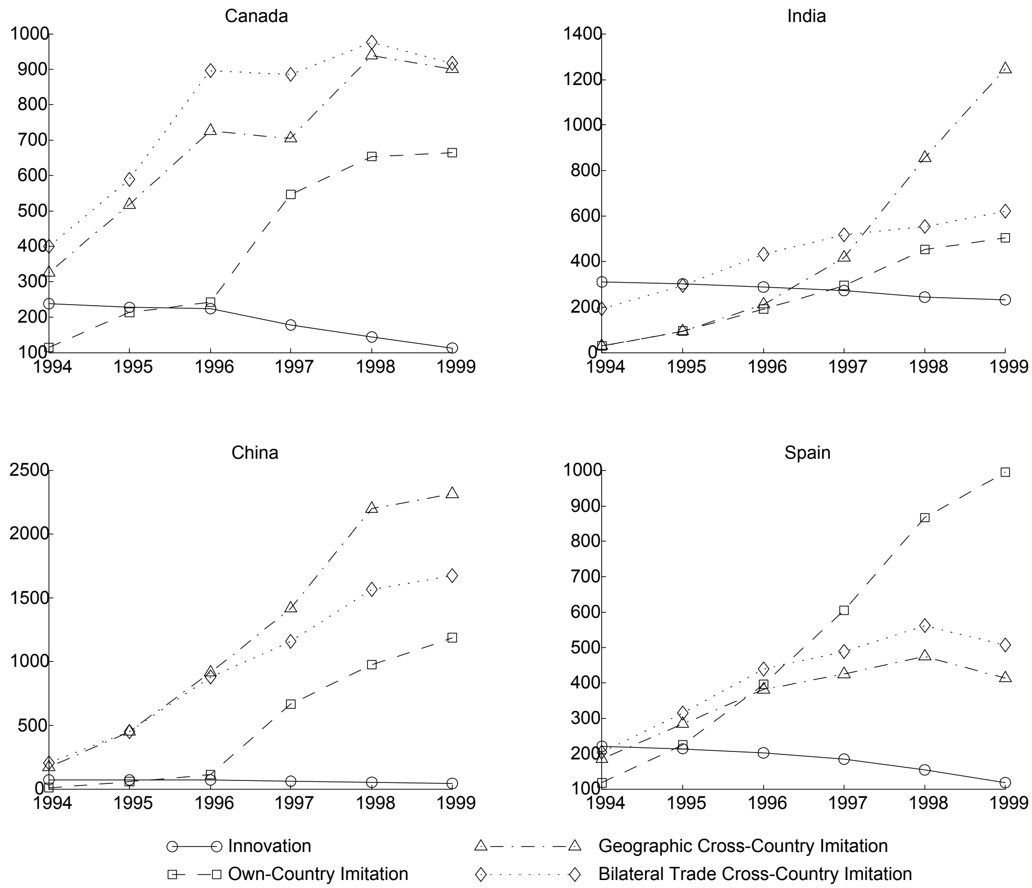

Figure 4: Number of new ISO 9000 certifications resulting from innovation, own-country and cross-country influence

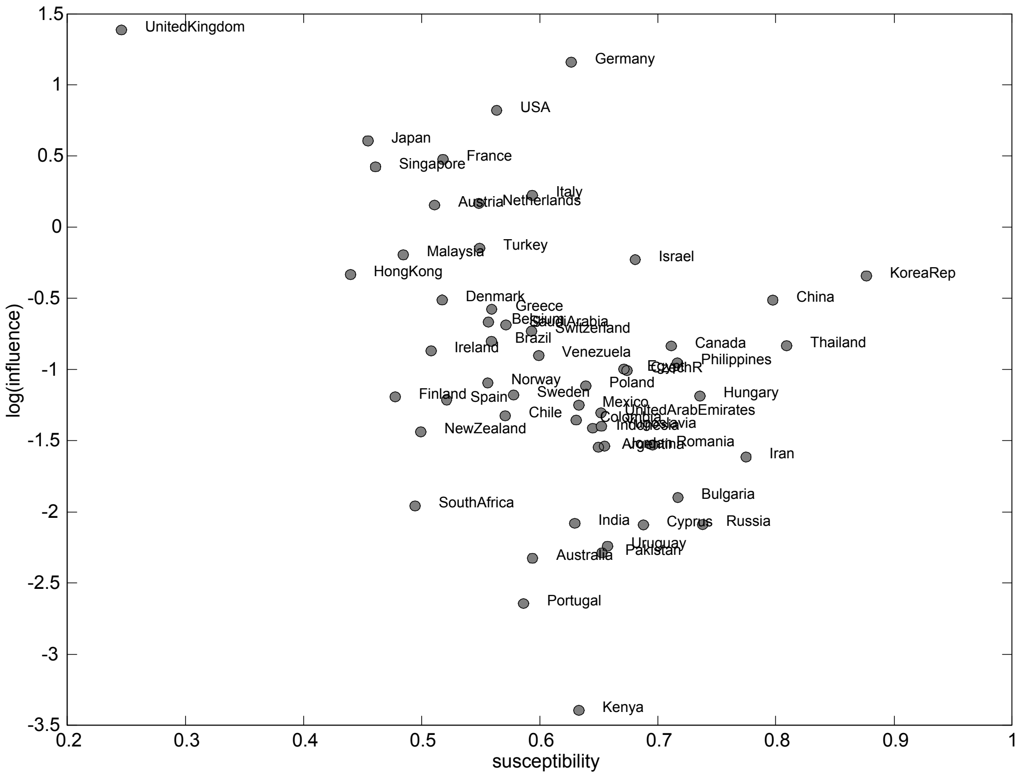

Figure 5: Influence and susceptibility values for ISO 9000 certification in the sampled countries