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TRANSFER IN CONTEXT: REPLICATION AND ADAPTATION IN KNOWLEDGE TRANSFER RELATIONSHIPS

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This paper explores the role of replication and adaptation in knowledge transfer relationships. I develop a model of knowledge transfer in which firms replicate because knowledge is ambiguous and adapt because knowledge depends on context. In the model, firms replicate more when knowledge is discrete and adapt more when they understand the interactions between different areas of knowledge. Replication and adaptation lead to successful knowledge transfer, which leads to improved performance of the receiving unit. The predictions are tested using a survey of cross-border knowledge transfer relationships among firms in the telecommunications industry. The results are largely consistent with the model and point to potential areas for future research, such as the drivers of replication, the depreciation rate of knowledge, and the role of understanding in organizational knowledge. Copyright © 2007 John Wiley & Sons, Ltd.

This paper presents a model of knowledge transfer that follows from the dual nature of knowledge—the fact that it is both ambiguous and context-dependent. Recognizing these two aspects of knowledge has several implications for knowledge transfer relationships. First, knowledge transfer will usually involve knowledge that requires replication and knowledge that requires adaptation. Second, if firms combine replication and adaptation in knowledge transfer, we need to change our understanding of replication in the transfer relationship as the absence of adaptation. I develop an approach to knowledge transfer that incorporates these insights and test this model on a sample of knowledge transfer relationships in telecommunications services.

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The idea that organizational knowledge is tacit and ambiguous has played a central role in research on strategy and organizations (Kogut and Zander, 1992; Nelson and Winter, 1982). Causal ambiguity is inherent to most complex production processes (Lippman and Rumelt, 1982), so firm members often do not understand the root causes of firm performance or the interaction between individual activities. Replication, which is effort towards exact copying of a set of activities, enables the transfer of those activities without the need to understand their causes, consequences, and interdependence. Thus, researchers have proposed that firms replicate knowledge to transfer it in the face of ambiguity (Winter and Szulanski, 2002).

Management scholars have also recognized the context-dependent nature of knowledge in organizations (Argote and Ingram, 2000; Kostova and Roth, 2002; Prahalad and Doz, 1987). The rich connection between organizations and their environment is a long-standing concern of organizational scholars (Henderson and Mitchell, 1997;

Nelson and Winter, 1982; Tushman and Anderson, 1986), and these links determine the composition of knowledge in the organization and its fit with the new environment. To transfer knowledge effectively in the face of context dependence, firms must adapt knowledge to a new setting.

These insights into knowledge have arisen in separate streams, however, so studies tend to emphasize either the need for replication or the need for adaptation. In this study, I find that firms are often engaged in both careful copying of practices from a partner and significant adaptation of practices. Accounting and reporting measures, for example, are frequently replicated because they are highly interdependent with the transferring partner. On the other hand, customer service practices and marketing are frequently adapted because of the extent to which they interact with the unique environment of each location. In other cases, replication and adaptation are combined within the same set of practices. A set of Latin American telephone companies balance replication and adaptation in their human resource practices. The firms replicate a set of common programs for the rotation, development, and compensation of managers. Each firm, however, adapts the exact positions and levels of the hierarchy to its own institutional environment.

The model of knowledge transfer presented in this paper recognizes the joint role that replication and adaptation play in a knowledge transfer relationship. In the model, replication rises when knowledge is more discrete, while adaptation rises when the receiving firm understands the knowledge it is getting. Replication and adaptation then lead to increased knowledge transfer, which in turn leads to greater performance gains at the receiving unit.

I study knowledge transfer relationships in the context of the telecommunications industry. A radically new set of tools—digital switching, fiber optic transmission, data transmission protocols, and wireless communications—have transformed the telecom sector. These new technologies are necessary to build a modern communications industry, but companies in less developed markets have found that technology alone is not sufficient. These firms have found they also require complementary knowledge, in the form of practices and information, to provide modern services. To acquire this complementary knowledge, many firms used the impetus of regulatory reform to form knowledge transfer relationships with industry leaders. To gather data on these relationships, I surveyed relationship partners.

The data from these surveys are largely consistent with the hypotheses presented in the paper, suggesting that replication and adaptation contribute to knowledge transfer, and that transfer contributes to improvements in receiver performance. The results also suggest that the most significant factor for facilitating adaptation is experience within the relationship, rather than prior transfer experience. Robustness analysis suggests that the performance gains from knowledge transfer depreciate rapidly. The evidence is not consistent with the hypothesized relationship between discrete knowledge and replication: it suggests that firms manage interdependence not by reducing replication, but by increasing adaptation.

A MODEL OF KNOWLEDGE TRANSFER

This section lays out five hypotheses, which form the basis of a model of knowledge transfer. I begin by outlining the primary aspects of organizational knowledge described by prior research, and how they suggest the need to replicate and adapt knowledge in the transfer process. I then discuss how to reconcile the use of replication *and* adaptation in the knowledge transfer process. I propose two contingencies that lead to higher levels of replication and adaptation, respectively. Finally, I hypothesize that replication and adaptation contribute to knowledge transfer, which then leads to performance improvements at the receiving unit.

Most theorists locate organizational knowledge in the actions of the organization. Nelson and Winter (1982: 99) 'propose that organizations *remember* by *doing*.' Similarly, Spender (1996) emphasizes that knowledge is inextricably linked to collective action in organizations. Nonaka (1994: 16) also suggests that 'knowledge is deeply rooted in action.' Thus, firms possess knowledge only if they can put it into action.

Other approaches to knowledge focus on the integration of diverse components of knowledge. Argote and Ingram (2000) propose that knowledge resides in three reservoirs within the firm—members, tools, and tasks—and in the networks that link them. In their framework, firms' performance depends on the extent to which these

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networks are compatible with each other and with the external environment. In a similar vein, Grant (1996) argues that knowledge resides in the organization's ability to take individual knowledge and integrate it.

These aspects of knowledge suggest two key characteristics of organizational knowledge: causal ambiguity and context dependence. Causal ambiguity (Lippman and Rumelt, 1982) arises because knowledge is embodied in the repeated activities of the organization, known as routines. Routines link together the actions of organization members, who may not understand, or even be aware of, actions elsewhere in the chain. Since these chains are long and incompletely understood, no member of the organization will completely understand the relationship between an organization's actions and outcomes (Nelson and Winter, 1982). On the other hand, context dependence arises because knowledge integrates components of knowledge—such as people, personal networks, or information—which vary between settings. Since compatibility between components is necessary for knowledge to be effective (Argote and Ingram, 2000), context will lead knowledge to vary in order to achieve similar outcomes while integrating differing components.

Since ambiguous causality and context dependence are fundamental aspects of organizational knowledge, knowledge transfer requires firms to resolve a number of uncertain relationships: the relationship between an activity and its outcome, the relationship between an activity and the rest of the organization, and the relationship between an activity and the firm's environment. Resolution of these relationships will involve a continuous process of modification and observation: change a practice, observe outcomes, observe interactions, change again. By applying iterative changes at the receiving unit followed by observations at the source and receiving units, firms can gradually copy practices from the source and integrate them with the new context, thus accomplishing knowledge transfer.

To study firms' approach to this process, I measure their transfer activities (replication and adaptation) and the outcome of those activities (knowledge transfer) in two defined periods: the first year of the knowledge transfer relationship, which varies between the firms, and the year of the survey, 2001. Data from the first year are used to test the structural model, which includes simultaneous relationships between replication and adaptation, knowledge transfer, and performance. Data from 2001 are used to compare the contingencies driving replication and adaptation early in the relationship to later periods.

This approach to knowledge transfer differs from recent studies in two key ways: the focus is the knowledge transfer relationship rather than the transfer of a single practice, and knowledge transfer is treated as the outcome of the process rather than a distinct point in the process. While recent studies of knowledge transfer focus on the transfer of a single, targeted practice (e.g., Kostova and Roth, 2002; Szulanski, 1996), knowledge transfer relationships frequently encompass a wide variety of areas targeted for transfer (Argote, 1999). For instance, the firms in this study face simultaneous pressure to expand networks, improve service quality, establish positive customer relationships, and eliminate waiting lists for service, so they turn to their partner for many types of knowledge. To manage the complexity of these multiple links in the knowledge transfer relationship, firms need to approach the transfer relationship with a consistent strategy, and the nature of these strategies is the focus of this study.

When a firm is engaged in a knowledge transfer relationship, it must decide how to allocate its effort with regard to two competing goals: changing the receiving unit's operations to be more like its partner's—replication—and changing its operations to integrate with local context—adaptation. Theoretical approaches to replication have emphasized the costly mistakes created by adaptation (Winter, 1995; Winter and Szulanski, 1998, 2002). From this perspective, replication reduces or rules out adaptation, which poses problems if, in addition to causal ambiguity, organizational knowledge exhibits context dependence. Though replication and adaptation are typically understood as opposing approaches to transfer, this study examines the possibility that firms might use them together.

The joint use of replication and adaptation suggests an apparent contradiction between copying a practice exactly and modifying it: at some fundamental level, exact copying and modification might be mutually exclusive. I resolve this conflict by treating replication and adaptation as effort towards a goal. Thus, I define *replication* as effort aimed at creating activities at one location that are identical to those at another location. Similarly, I define *adaptation* as effort toward the

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goal of modifying or combining practices from a source unit. Replication and adaptation are modes, then, by which organizations accomplish *knowledge transfer*, which I define as the acquisition from another unit of useful information or practices. This approach allows for combined modes of transfer: an organization can invest substantial effort towards exact copying, but still invest some effort in adaptation in areas where exact copying is difficult or impossible. This might arise if a firm is working to copy a complex and successful set of practices for dispatching network maintenance teams quickly, but also needs to adapt them to the nature of local infrastructure—for instance, whether lines are strung above ground on poles or underground in sewers.

Whether firms typically combine these modes of transfer or whether replication arises separately from adaptation is a question that can be empirically resolved. To distinguish whether replication and adaptation are two ends of a single spectrum of transfer practices or two separate modes of transfer, we can test whether they vary together or separately. If replication and adaptation are mutually exclusive transfer strategies then the two will vary inversely—as replication rises, adaptation will fall, and vice versa. In this case, they can be represented as opposite indicators of a single construct of transfer mode. In contrast, when replication is defined as effort they may vary separately—replication may rise without affecting adaptation and vice versa. If the two vary independently, a factor model with two transfer modes will fit the data better than one with a single construct of transfer mode. This leads to my first hypothesis.

Hypothesis 1: Replication and adaptation by the receiving unit represent two separate constructs rather than a single continuum of transfer mode.

Levels of replication and adaptation

If replication and adaptation vary separately, specific contingencies will lead them to rise and fall. I propose that replication will rise when knowledge is more discrete and adaptation will rise when firms understand the interactions between different areas of knowledge.

A firm's knowledge is more *discrete* when it is more self-contained, with fewer connections to actors outside the firm, such as customers, suppliers, or local institutions and infrastructure. When knowledge is more discrete, the costs of replication are lower because the unit may copy a set of activities with less consideration of their external links. It will be harder and more expensive to replicate knowledge that is less discrete because it is intertwined with areas outside the firm. If a firm replicates highly interconnected knowledge without context or related areas of knowledge, it will find this knowledge less well integrated, and less useful. It follows, then, that the cost of replicating knowledge falls as knowledge becomes more discrete. As these costs fall, I expect that firms will invest more in replication.

Hypothesis 2: When knowledge to be transferred is more discrete, replication by the receiving unit will be higher.

Adaptation, on the other hand, can be costly because of the challenge of predicting interactions between interdependent knowledge in the organization (Winter and Szulanski, 2002). When a firm makes more accurate predictions of the interaction between a potential business practice and other parts of the organization, adaptation will be less costly. In interviews, some participants in transfer relationships pointed to the ability to understand interdependence as an essential practice for successful knowledge transfer. I define *understanding of knowledge* to represent two capabilities: the ability to predict how a change in one area of knowledge will affect other parts of the organization and the ability to identify the essential elements of a set of practices. Understanding enables the firm to tailor changes by anticipating interdependence and thereby reduces the unintended problems from adaptation. Increasing the effectiveness of adaptation reduces the costs of adaptation. Thus, I predict adaptation will increase with understanding.

Hypothesis 3: When the units possess greater understanding of their knowledge, adaptation by the receiving unit will be higher.

A structural model of transfer and performance

I have proposed that adaptation and replication are separate mechanisms for transfer and that firms vary their use based on contingent factors of discrete knowledge and understanding. Next, I present

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three hypotheses that complete a structural model. The full model begins in the previous section with the contingencies leading to higher replication or adaptation. The next two hypotheses propose that replication and adaptation will each contribute to knowledge transfer. The final hypothesis proposes that knowledge transfer will lead to subsequent improvements in performance at the receiving unit.

Replication leads to knowledge transfer because it is necessary to create a new working copy of complex and ambiguous knowledge (Winter, 1995). When knowledge is complex and causally ambiguous, a firm may not be able to predict which elements of the knowledge are essential for its effective operation. By investing significant effort in copying a set of practices exactly—replicating—a firm insures that the transferred practices contain any elements of the knowledge that might turn out to be essential. A set of practices with all essential elements is more likely to be effective, and when new practices are more effective they will be more valuable to the receiving partner. This represents increased knowledge transfer. Thus, the more a receiving unit invests in replication the greater the knowledge transfer it will accomplish.

Hypothesis 4a: The greater the level of replication by the receiving unit, the greater the knowledge transfer to the receiving unit.

Transfer only helps firms if the knowledge is suited to the new context. Many lines of research on strategy, technology, and international business suggest that knowledge depends on its context. Argote and Ingram (2000: 159) argue that compatibility between networks of knowledge reservoirs is difficult to replicate in a new environment. Winter (1995: 154) points out that replication will often be accompanied by adaptation: 'In many actual cases the objective is not exact replication but partial replication, accompanied by adaptive or innovative change in some routines.' Allen (1977) proposes that firms require technological gatekeepers because technical knowledge from other organizations needs to be translated for use within the firm. Leonard-Barton (1988) finds that the implementation of a new production technology requires mutual adaptation between the technology and organization to such an extent that it is best understood as an extension of the innovation process. Empirical studies have found that multinationals adapt human resource practices to local institutions (Kostova and Roth, 2002).

Adaptation increases the total amount of knowledge transfer because it reduces the cost of transferring a valuable set of practices. Without adaptation, replication has inconvenient cascading implications. When using high levels of replication without any adaptation, a firm that targets a set of practices for transfer will also need to replicate any activities that are linked with the focal practices. These linked activities will have links of their own, creating a widening set of practices that must be replicated simply to acquire the original target. Adaptation can reduce the cost of transfer by modifying the connections between a set of practices and the rest of the organization or environment, allowing those practices to be targeted without replicating related areas. Adaptation enables firms to focus on potentially valuable knowledge and integrate it with the new context.

In addition, adaptation can make transferred knowledge more effective. The effectiveness of organizational knowledge depends on the integration of diverse components of knowledge (Argote and Ingram, 2000; Grant, 1996). Some of these diverse components of knowledge must vary in new contexts, so specific practices will need to change to integrate them. For instance, if the legacy switching equipment for the existing telephone network is made by a local supplier, then the firm's management systems must be changed to monitor and manage the legacy equipment.

Thus, when firms engage in adaptive efforts they will be able to transfer more knowledge and make that knowledge more effective in the new context.

Hypothesis 4b: The greater the level of adaptation by the receiving unit, the greater the knowledge transfer to the receiving unit.

Scholars generally posit that knowledge transfer is a key source of competitive advantage, but the hypothesized link between knowledge transfer and performance is rarely verified. Kogut and Zander (1992) argue that successful firms must be able to replicate their organizational knowledge to grow. Winter proposes that knowledge is a strategic asset (Winter, 1987) and a source of rents for firms (Winter, 1995). Argote and Ingram (2000) hypothesize that knowledge transfer is a basis for the competitive advantage of firms, since the effectiveness of transfer varies considerably among

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organizations. Still, most studies of knowledge transfer either focus on transfer alone through survey measures (Gupta and Govindarajan, 2000; Szulanski, 1996; Winter and Szulanski, 1998) or use performance improvements in the presence of transfer relationships to proxy for knowledge transfer (Ahuja, 2000; Argote, 1999; Baum and Ingram, 1998; Darr, Argote, and Epple, 1995).

Knowledge transfer leads to performance improvements because the valuable new practices and information enable the firm to accomplish its goals more quickly and at lower cost, and even accomplish new goals. Nelson and Winter (1982: 123) point out that access to a source unit's template is a key ingredient for successful knowledge transfer, otherwise '[w]hen problems arise in the copy, it is not possible to resolve them by closer scrutiny of the original.' Without access to the template, a firm that wishes to acquire knowledge has little information to work with. Since the most important elements of organizational knowledge tend to be tacit, the ability to observe, ask, articulate, and check is an essential element of improving the effectiveness of practices through knowledge transfer relationships. Because of the ability to clarify and explore complex relationships in the template, knowledge transfer relationships help firms acquire the most complex, and often most valuable, practices, which will improve the performance of the receiving unit.

Even when an organization is not engaged in wide-scale copying of practices, information from a successful partner can help solve pressing problems an organization faces. When firms face problems, they search their information environment for potential solutions (Cyert and March, 1992; Nelson and Winter, 1982). The knowledge transfer relationship gives the receiving firm more information on potential solutions, which improves the changes it makes.

Hypothesis 5: Greater knowledge transfer will lead to higher performance at the receiving unit.

When we recognize that ambiguity and context dependence arise from the fundamental nature of organizational knowledge, a more complete picture of the knowledge transfer process emerges. Firms replicate because some knowledge is ambiguous and adapt because some knowledge depends on context. While the two transfer modes have been treated as mutually exclusive, I define them as effort toward copying and modifying practices, which allows for replication *and* adaptation in knowledge transfer. In the model, replication rises when knowledge is more discrete while adaptation rises when firms understand interactions between knowledge and context. Replication and adaptation each contribute to knowledge transfer, and knowledge transfer leads to higher performance at the receiving unit.

DATA AND METHODS

This section explains my empirical approach. I discuss the advantages of the empirical setting for studying knowledge transfer. I explain the data collection methods and statistical analysis. Finally, I describe the variables used to represent the primary constructs.

Empirical setting

I test the theoretical model in the context of international transfer relationships among telecommunications service firms. These relationships have a number of characteristics that make them an interesting setting to study knowledge transfer. The relationships were formed with the express purpose of transferring knowledge, and the source partners were frequently chosen for their ability to transfer knowledge. There is a clear source of knowledge and receiver of knowledge in these settings, so the outcome of the relationship is more straightforward than in other relationships where transfer can be non-cooperative and in both directions. In addition, the telecom service industry features a high level of tacit knowledge that firms must employ to provide service effectively. There is an array of advanced equipment, but complementary organizational knowledge is required to operate the equipment effectively.

The rapid diffusion of new telecommunications equipment also means that the operating routines of advanced telecom firms have some relevance to firms in less developed markets. On the other hand, the industry still features multi-domestic competition, in which coordinated international strategies do not play an important role. Thus, replication is less likely to be imposed by the need for coordination.

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Data collection

I use a survey and additional archival measures as sources of data on the firms and settings for these transfer relationships. The population of relationships studied here are cross-border investments in fixed-telephone and cellular service providers. I targeted firms in these relationships using information from Pyramid Research (a former division of the Economist Intelligence Unit that performs market research on telecommunications markets around the world) and RCR Wireless, a publisher focused on the wireless industry. I defined the relationships as those in which a multinational telecommunications firm invested (minority or majority stake) in a local telecommunications firm. I gathered contact information for 324 unique relationships using RCR's Global Wireless Database, Dunn & Bradstreet, and company reports.

I developed the survey through a modified version of Dillman's Tailored Design Method (Dillman, 2000). The survey asked respondents to rate each item on a five-point Likert scale (agree/disagree) for the current year (2001) and for the first year of the relationship (which varies by firm). These items served as indicators for the constructs of replication, adaptation, and knowledge transfer (see Variables section). I mailed the surveys to the top decision-maker at each of the firms in two batches in late summer and early fall 2001. Follow-up to the survey included a post card 3 weeks after the survey mailing, phone calls to the targeted respondent, and regular emails to those who planned to complete the survey but had not yet returned it.

At the end of this process, I received 62 completed surveys for a final response rate of 19 percent. Two of those responses were from relationships begun 30–40 years earlier, so I did not include them in the final analysis. I compared the respondents to the 324 targets for three country characteristics: gross national income (GNI), population, and telephone penetration (lines per 100 inhabitants). Based on a comparison of means test, I did not find a significant difference between the responses and the targeted firms for GNI or population. I also performed a Kolmogorov–Smirnov nonparametric comparison of the samples and found that they did not differ based on population. I did find a difference between the means of responses and target firms for telephone penetration. In addition, the Kolmogorov–Smirnov test, which detects clustering in the response sample (Conover, 1971), found that the survey responses cluster in some areas of GNI even though the means did not differ. Overall, the response sample is similar to the target in basic country characteristics of population and income, but it differs in terms of telecommunications development (slightly higher) and income levels (clustered data).

Analysis

I test the hypotheses in the context of a structural equation model (SEM), which represents the simultaneous relationships between replication and adaptation, knowledge transfer, and performance of the receiving unit. This allows me to test the relationships in a framework that accounts for the direct and indirect relationships between these variables. The structural model also includes a measurement model, which corrects for measurement error in latent constructs (e.g., knowledge transfer) by using multiple observed indicators of them.

The number of observations is low by the field's rules of thumb for SEM. Small samples are known to bias fit statistics downward, leading to over-rejection of true models (Hu and Bentler, 1999). A study, which examined the effect of sample size on parameter estimates, however, found no evidence of bias; most of the problems from small samples arose because of non-convergence of the estimation algorithms (Marsh *et al*., 1998). Since the focus of this study is the relationship between key constructs, which are represented by the parameter estimates, I use SEM to test the hypotheses while accounting for measurement error, which is a common problem with survey studies. I also conduct considerable robustness analysis to check if the findings are stable across different specifications that reduce estimation problems or increase discriminatory power. I present alternative results based on ordinary least squares (OLS) regression, which has better small sample estimation properties than SEM. The small sample limits the discriminatory power of the study in any specification, however, so the results are most likely to be valid for large effects but may under-report the significance of small effects.

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Tests of performance, such as Hypothesis 5, are fraught with selection problems because firms make investment decisions based on anticipated performance benefits (Masten, 1993; Shaver, 1998). Selection problems arise when a population is not randomly selected from among the possible population parameters (Greene, 2003; Heckman, 1979; Maddala, 1983). In this case, selection bias could arise because the firms choose their efforts toward replication and adaptation with some foresight. When higher performance from transfer is anticipated, the firms are likely to invest more in replication and adaptation. A structural model can include this effect by modeling the selection mechanism directly and allowing the error terms to correlate between the selection criteria and the outcome (Greene, 2003; Maddala, 1983; Muthen and Joreskog, 1983). This is analogous to maximum likelihood estimation of selection in simultaneous equations (Greene, 2003). Conveniently, Hypotheses 2 and 3, along with a number of controls for country attractiveness and firm size, directly model firms' propensity for replication and adaptation.

Identification of the parameters is a serious issue in structural equation models (Bollen, 1989; Goldberger, 1991; Greene, 2003), since not all specified models may be estimated in the population. The structural model presented in this paper is identified by Bollen's two-step rule (Bollen, 1989: 328): the measurement model is identified by the three-indicator rule and the structural model is identified by the rank and order conditions for non-recursive models.

The models were estimated using full-information maximum likelihood in AMOS 5.0, which uses all available data to estimate the model. This approach provides consistent and efficient estimators if the data are missing completely at random and is consistent if the data are missing at random (Arbuckle, 1996; Arbuckle and Wothke, 1999). There are 40 missing values out of 2400 data points in this set. The missing values are clustered in the performance measure (nine missing values) and the subscriber data (seven missing for receiver, four missing for source).

I conducted all significance and hypothesis tests using likelihood ratio tests, which are scale independent (Gonzalez and Griffin, 2001; Greene, 2003). This is a significant issue for SEM, since all latent variables are scaled, but defaults in most statistical packages rely on Wald tests, which may vary with different scales assigned to a parameter. Generally, this approach reduced the level of significance of the relationships compared to the *p*-values from Wald tests.

Variables

Appendix 1 presents descriptions and descriptive statistics for all 42 observed variables in the study, including the survey items used to measure the latent constructs of replication, adaptation, and knowledge transfer. Appendix 2 presents the correlation of these variables.

Table 1 presents the items representing the latent variables of knowledge transfer, replication, and adaptation, as well as the results of the measurement model using the responses referring to the first year of the relationship (the reliability of the constructs is even higher for the 2001 data). Each construct is represented by three or four survey items, which span different aspects of the construct. Each of the items loads significantly on the construct, and the reliability indicator (Cronbach's alpha) is well above the standard 0.7 cut-off for all three constructs. In addition, the measurement model demonstrates very close fit with the observed data and a non-significant χ^2 test. Thus, confirmatory factor analysis suggests that the measurement model demonstrates high reliability and a close fit with the observed data.

The additional variables are described below.

Discrete knowledge

Three measures represent the extent of links between knowledge in the receiving firm and outside actors, institutions, and infrastructure—that is, between the firm and the outside environment. The variable *cell*, which was coded from survey responses, indicates whether the firm operates only in the cellular telecommunications market. Cellular firms have fewer links with the environment because regulators do not impose universal service obligations and because the infrastructure does not require installation in every neighborhood. The variable *new* indicates whether the receiving firm was founded at the same time as the transfer relationship, which was coded from surveys. Historical routines will acquire connections to the environment as they face new contingencies over time, which makes them less discrete. The variable *template* indicates whether the source firm

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Table 1. Measurement of latent constructs

Latent variable (*Cronbach's* α)	Survey items (item number, refers to initial year of relationship)	Estimates	S.E.
Knowledge transfer ($\alpha = 0.89$)			
	Our partner provided valuable information for our business (pb1)	1.07***	0.15
	We learned a lot from our partner (pb2)	1.40***	0.19
	Our partner provided examples of new ways to manage our business (pb3)	1.00	
Replication ($\alpha = 0.89$)			
	We tried to manage our business exactly like our partner (pc1)	0.77***	0.13
	We tried to implement practices from our partner exactly as they existed (pc5)	1.11***	0.12
	We tried to copy practices from our partner down to smallest detail (pc6)	1.00	
	We spent substantial time making sure practices we adopted from our partner worked just as they did there (pc7)	0.90***	0.12
Adaptation ($\alpha = 0.84$)			
	We usually modified practices from our partner when we implemented them in our business (pe1)	1.00	
	We usually combined ideas from our partner with other ideas when we adopted them (pe4)	0.88***	0.13
	We spent substantial time modifying practices from our partner to make them work in our business (pe5)	0.64***	0.15
	We carefully selected practices from our partner to adopt in our business (pe6)	0.96***	0.15
		Model fit	
	χ^2 (d.f.)	53.22 (41)	
	IFI (delta 2)	0.97	
	CFI	0.97	

Significant at * 0.10 level; ** 0.05 level; *** 0.01 level (by one-tailed likelihood ratio test).

had operations in its home country and was drawn from company reports. Firms without home operations are more likely to transfer knowledge from multiple source locations, introducing connections with multiple source environments. As a result, firms with a home template possess more discrete knowledge.

Understanding

Three measures represent the degree to which the transfer partners build understanding of their knowledge through experience. The variable *scountries* represents the number of countries where the source firm provided telecom services in 2001 (from company reports). Source units build understanding of connections through repeated transfer. The variable *srelat* represents the number of source–firm relationships within the same country as the receiving firm (from company reports). This variable represents source-unit understanding of the specific country setting built through multiple relationships. The variable *time* indicates the number of years the knowledge transfer relationship had existed in 2001 (from survey responses). This variable represents understanding built through experience in this relationship.

Performance

The performance of the receiving firm is measured as improvements in efficiency in the year after the knowledge transfer relationship was founded. Efficiency is measured as the number of subscribers per employee. This figure is calculated for the end of the first year of the relationship and the end of the second year of the relationship. The variable *edelt12* is defined as the percentage change in this measure between the first year and the second year of the relationship.

Controls

A number of controls for country attractiveness and firm characteristics are included in the model to account for the relative propensity of firms to invest in replication and adaptation. *Year* represents the year the relationship was founded, which was coded from survey responses. *Lnrecsubs* represents the natural logarithm of receiving firm

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subscribers in 2001, which was coded from survey responses and company reports. *Lnsrcsubs* represents the natural logarithm of source-firm subscribers (in all countries, equity adjusted) in 2001, which was coded from company reports. *Lngni01* is the log of gross national income per capita in 2001, while *lngdp_i* is the log of GDP per capita for the first year of the relationship. These variables were coded from the World Bank Development Indicators. *Lnpop01* is the log of the national population of the receiving firm's country in 2001, while *lnpop_i* is the log of the population in the first year of the relationship. The population variables were coded from the World Bank's (2002) *World Development Report. Telpen01* is the number of telephone lines per 100 inhabitants in the target country in 2001, while *telpen_i* is the telephone penetration in the first year of the relationship. The telephone penetration data were gathered from the International Telecom Union. *Polcon* is a measure of political risk for the receiving country in 2001, while *polcon_i* is the same measure of political risk in the initial year (Henisz, 2002). *Currown* is the source firm's ownership stake in the receiving firm in 2001, while *firstown* is the source firm's ownership at the beginning of the relationship. These were coded from survey responses.

RESULTS AND DISCUSSION

Tables 2 and 3 present the results of the analysis. The models build from a regression with latent

Table 2. Levels of replication and adaptation (2001)

	Hypothesis (predicted sign)	Model 1 Contingencies	Model 2 Contingencies plus time	Model 3 Contingencies plus time, source, and size
currown → R		0.32**	0.32**	0.34***
lngni01 → R		−0.42*	−0.42*	−0.28
lnpop01 → R		0.05	0.05	−0.09
telpen01 → R		−0.17	−0.18	−0.35
polcon → R		0.22	0.23	0.22
cell → R	H2 (+)	0.19	0.19	0.17
new → R	H2 (+)	−0.14	−0.14	−0.07
template → R	H2 (+)	0.18	0.18	−0.10
time → R			−0.02	−0.09
scountries → R				−0.10
srelat → R				−0.14
lnsrcsubs → R				0.48
lnrecsubs → R				0.06
currown → A		0.37***	0.39***	0.35***
lngni01 → A		−0.10	−0.16	−0.19
lnpop01 → A		0.12	0.16	0.01
telpen01 → A		0.05	0.20	0.19
polcon → A		0.31*	0.25	0.20
cell → A		−0.47***	−0.40***	−0.59***
new → A		0.37***	0.23	0.44***
template → A		0.10	0.10	0.01
time → A	H3 (+)		0.31**	0.27**
scountries → A	H3 (+)			0.02
srelat → A	H3 (+)			−0.08
lnsrcsubs → A				−0.06
lnrecsubs → A				0.41***
χ^2 (d.f.)		155.69 (108)	149.94 (106)	132.74 (98)
IFI (delta 2)		0.93	0.94	0.95
CFI		0.92	0.92	0.94

$n = 60$; standardized coefficients; significance by one-tailed likelihood ratio tests; 2001 data; A represents latent construct for adaptation; R represents latent construct for replication; relationships between indicators and latent variables and between independent variables (IVs) are suppressed for brevity; models are nested with all IVs included in each model. Significant at * 0.10 level; ** 0.05 level; *** 0.01 level.

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dependent variables (replication and adaptation) to a full structural model in which adaptation and replication lead to knowledge transfer, which in turn leads to performance improvements. The models are nested by including all variables in each estimated model, but gradually adding the relationships between the variables. Table 2 presents Models 1–3 using 2001 data to test Hypotheses 2 and 3. Table 3 presents Models 4–7 using data from the beginning of each knowledge transfer relationship to test Hypotheses 4 and 5. Model 1 examines the relationship between adaptation and replication and eight exogenous variables. Model 2 adds the exogenous variable time to Model 1. Model 3 adds several source and receiving-firm variables to Model 2. Model 4 replicates Model 2 with data from the first year of the knowledge transfer relationship (year substitutes for time, but the two variables have a perfect, inverse correlation). Model 5 adds the effect of adaptation and replication on knowledge transfer. Model 6 adds the effect of knowledge transfer on performance improvements. Model 7 incorporates potential selection bias arising when firms invest more in transfer mechanisms based on expectations of performance improvements. Finally, Table 4 recreates the components of Models 3 and 6 using ordinary least squares. Overall, the results are consistent with a model of replication and adaptation as separate constructs that both contribute to knowledge transfer, which leads to performance improvements. The results are mixed

Table 3. Structural model of knowledge transfer and performance (first year)

	Hypothesis (predicted sign)	Model 4 Adaptation and replication contingencies	Model 5 Adaptation, replication and transfer	Model 6 Transfer and performance	Model 7 Full model w/selection
firstown → R		0.09	0.08	0.08	0.09
lngdp_i → R		0.01	0.00	0.00	0.00
lnpop_i → R		−0.12	−0.12	−0.12	−0.12
telpen_i → R		−0.28	−0.26	−0.26	−0.27
polcon_i → R		−0.05	−0.05	−0.05	−0.05
cell → R		−0.04	−0.03	−0.03	−0.03
new → R		0.14	0.14	0.14	0.14
template → R		0.16	0.16	0.16	0.16
firstyear → R		−0.21	−0.21	−0.21	−0.21
firstown → A		0.17	0.16	0.16	0.14
lngdp_i → A		−0.27	−0.28	−0.28	−0.29
lnpop_i → A		0.27	0.27	0.27	0.30*
telpen_i → A		0.45*	0.46*	0.46*	0.46*
polcon_i → A		0.04	0.05	0.05	0.08
cell → A		−0.44**	−0.42**	−0.42**	−0.36*
new → A		0.41**	0.40**	0.40**	0.43**
template → A		−0.03	−0.02	−0.02	−0.02
firstyear → A		−0.00	−0.00	−0.00	0.04
R → KT	H4a (+)		0.40***	0.40***	0.40***
A → KT	H4b (+)		0.40***	0.40***	0.41***
KT → *edelt12*	H5 (+)			0.25*	0.34*
errorR—errorp					0.02
errorA—errorp					−0.23
χ^2 (d.f.)		225.82 (145)	204.23 (143)	201.26 (142)	199.75 (140)
IFI (delta 2)		0.88	0.91	0.91	0.91
CFI		0.86	0.89	0.90	0.90

$n = 60$; standardized coefficients; significance by one-tailed likelihood ratio test; data from initial year of relationship; A represents latent construct for adaptation; R represents latent construct for replication; KT represents latent construct for knowledge transfer; *errorR—errorp* and *errorA—errorp* represent the correlation of the error terms for replication and adaptation (respectively) with the error term for *edelt12*; relationships between indicators and latent variables and between independent variables suppressed for brevity; models are nested with all IVs included for each model.
Significant at * 0.10 level; ** 0.05 level; *** 0.01 level.

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Table 4. OLS regression of components of the structural models (Models 6 and 3 from Tables 2 and 3)

Initial year:	(1) DV: replicate	(2) DV: adapt	(3) DV: Ktx	(4) DV: *edelt12*	*2001*:	(5) DV: replicate	(6) DV: adapt	(7) DV: Ktx
firstown	−0.001	−0.013			*curr_own*	0.098**	0.083***	
	(0.057)	(0.036)				(0.052)	(0.032)	
lngdp_i	1.243	−0.492			*lngni01*	−0.784	−0.290	
	(2.108)	(1.337)				(2.198)	(1.362)	
lnpop_i	−1.339	0.543			*lnpop01*	−0.180	0.339	
	(1.612)	(0.731)				(1.058)	(0.656)	
telpen_i	−0.174*	0.080			*telpen01*	−0.141	0.047	
	(0.113)	(0.071)				(0.115)	(0.071)	
polcon_i	−4.296	0.198			*polcon*	7.657	3.553	
	(6.883)	(4.357)				(6.944)	(4.303)	
cell	1.040	−2.404			*cell*	4.470*	−5.810***	
	(3.244)	(2.042)				(3.281)	(2.033)	
new	1.610	2.769*			*new*	−3.415	3.871**	
	(2.999)	(1.890)				(3.203)	(1.985)	
template	1.177	−2.841			*template*	−0.593	−1.259	
	(3.908)	(2.477)				(4.995)	(3.095)	
firstyear	−0.465	−0.094			*time*	−0.103	0.465**	
	(0.389)	(0.245)				(0.371)	(0.230)	
					scountries	−0.036	0.006	
						(0.135)	(0.083)	
					srelat	−0.838	−0.369	
						(0.770)	(0.477)	
					lnsrcsubs	2.456**	−0.389	
						(1.404)	(0.870)	
					lnrecsubs	0.137	1.065***	
						(0.651)	(0.404)	
replicate_i			0.165***		*replicate*			0.248***
			(0.047)					(0.49)
adapt_i			0.221***		*adapt*			0.209***
			(0.070)					(0.062)
ktx_i				0.078*				
				(0.054)				
Intercept	945.673	209.668	3.336**	−0.158	Intercept	−19.528	9.237	1.361
	(772.880)	(486.403)	(1.489)	(0.621)		(25.145)	(15.581)	(1.457)
Observations	56	55	58	51	Observations	47	47	60
R^2	0.16	0.13	0.35	0.04	R^2	0.37	0.50	0.44

Data from 2001 survey; latent variables represented by sum of observed indicators; significance by one-tailed Wald tests. Significant at * 10%; ** 5%; *** 1%.

for the contingencies affecting replication and adaptation.

The results of confirmatory factor analysis are consistent with Hypothesis 1. When the indicators of adaptation and replication are constrained to a single factor in the measurement model, the model fit declines sharply over a model with two factors that correlate freely. The difference between the two models is highly significant, with a χ^2 (d.f. = 1) of 14.2. As described above, the baseline measurement model cannot be rejected by the data, while the model with a single factor is significantly at odds with the data ($\chi^2(42) = 67.4$, $p = 0.008$). In addition, when the indicators are loaded on a single factor, all the item loadings are positive, while one would expect one set of loadings to be negative in the one-factor case. Finally, in the two-factor model adaptation and replication have a positive, albeit non-significant, correlation. Thus, the data are consistent with the proposition that adaptation and replication are separate constructs.

The proposition that replication increases with discrete knowledge (Hypothesis 2) is not supported, since the variables representing discrete

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knowledge (*new, template*, and *cell*) do not have a significant relationship with replication. The variable *new*, which indicates whether the receiving unit was founded at the same time as the transfer relationship, does not significantly affect replication. In addition, its effect varies between positive (first year, Table 3) and negative (2001, Table 2), so while it is possible that the effect is too small to be distinguished from a non-effect with this sample, it does not appear to have a consistent impact on replication. In contrast to its lack of effect on replication, the variable *new* is also associated with significantly higher levels of *adaptation* in Tables 2 and 3.

Similarly, the existence of a clear home template (*template*) does not significantly increase replication among these firms. The relationship between *template* and replication is not significant in any of the models, though it is generally positive and could be small but significant with a larger sample. Finally, the variable *cell* does not lead to significantly higher replication in any of the models, except in one instance in the OLS regression (Table 4, column 5) where it is weakly significant. In addition, the effect changes from negative (first year, Table 3) to positive (2001, Table 2). The impact of *cell* on adaptation, however, is negative and significant in all models. While these firms do not significantly increase replication of more discrete knowledge in cellular markets, they do reduce adaptation in this setting.

The prediction that replication would rise as knowledge became more discrete relied on a cost mechanism, in which firms would turn to replication as the cost of integrating knowledge fell. Instead, these results suggest that firms choose a level of replication based on the reward for the transfer of ambiguous knowledge, and then choose a level of adaptation to achieve integration contingent upon the interdependence with the context. The lack of a relationship between indicators of discrete knowledge and replication might also arise if firms make knowledge more discrete by accounting for contingencies within the knowledge itself.[1] Alternatively, the relationship between discrete knowledge and replication might be masked in this study if replication is largely dependent on the policies of the source unit rather than the receiving unit. Secondary analysis using receiving-firm reports of source-firm investments in replication, however, found that none of these measures of discrete knowledge led to significant variation in source-firm replication.

The results are mixed with regard to the impact of understanding on adaptation (Hypothesis 3). In Models 2 and 3, adaptation increases significantly as the length of the relationship rises (time). Thus, understanding gained through experience in the relationship does increase the use of adaptation by the receiving partner. Relationship-specific experience appears to be necessary for building understanding, since the source firm's prior relationships (*scountries*) and country experience (*srelat*) do not have a significant impact on adaptation in Model 3. The lack of a relationship between source-firm experience and adaptation could arise because source firms that operate in many countries must impose uniform practices to reduce coordination costs. One might also conclude that these variables affect source adaptation without changing receiver adaptation, but secondary analysis using receiving-firm reports of source adaptation found that neither of these measures led to significant variation in source-firm adaptation.

The results are consistent with Hypotheses 4a and 4b. Replication and adaptation each have a positive and highly significant impact on knowledge transfer (see Table 3, Models 5–7). Firms that engage in higher levels of replication and adaptation also report greater transfer of knowledge from the source partner. These relationships are robust to all specifications of the model and are significant at the .01 level. The size of the effect is about the same for each mechanism—a one standard deviation increase in adaptation or replication leads to a 0.4 standard deviation increase in knowledge transfer.

Finally, knowledge transfer has a positive, significant impact on efficiency improvements (Hypothesis 5) in Models 6 and 7. This result

[1] For instance, if a manufacturing process depends on temperature or humidity, the knowledge may include operating routines that are contingent upon these context variables. I am grateful to a referee for pointing out this potentially endogenous aspect of discrete knowledge. However, if firms are generally successful in incorporating contingencies into the knowledge to be transferred, then we might see fairly uniform replication across different relationships with context. In this case, however, I would not expect to see the reduction of adaptation in the face of more discrete knowledge that is observed in all specifications. In addition, I would expect firms to develop this contingent knowledge (which can be more easily replicated) through the experience of repeated transfer, but there is not a significant relationship between past transfer (*scountries*) and replication.

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is somewhat larger when selection bias is accounted for by allowing errors to correlate between investments in mechanisms and impact on performance in Model 7. Since firms are likely to invest more when they anticipate performance pay-offs, this suggests that a selection bias may exist in the data, though the correlation between errors is not significant.[2]

Of the controls included in the study, the ownership variable has the strongest effect on replication and adaptation, though only in the 2001 data. Ownership of the source firm has a positive and highly significant impact on replication and adaptation in 2001. Firms appear to invest more in both replication and adaptation when the source owns more of the receiving firm. This is consistent with governance theories that predict knowledge transfer hazards are reduced by governance under a single firm (Oxley, 1999). In the data from the initial year of the relationship, however, source ownership does not have a significant effect on adaptation or replication. This might arise if source firms believed that investments in knowledge transfer will allow them to acquire higher levels of ownership in the future despite the risk of opportunism.

Country attractiveness has surprisingly little effect on adaptation. Telephone penetration is associated with more adaptation in the initial year of the relationship (*telpen* in Table 3, Models 4–7), though not in the 2001 data (Table 2, Models 1–3). Firms in countries with higher telephone penetration possess more technical understanding, which might increase the effectiveness of adaptation. Higher penetration is also associated with earlier liberalization, and competitive pressures early in the relationship may make adaptation essential for success. Larger receiving firms adapt significantly more (*lnrecsubs*), possibly because they have more links to the environment than smaller firms. Country size (*lnpop*) and political risk (*polcon*) have a positive, non-significant effect on adaptation in both time periods, while GNI per capita (*lngni01* in Table 2) and GDP per capita (*lngdp_i* in Table 3) have negative but non-significant effects.

On the other hand, replication has a generally negative relationship with measures of country attractiveness. GNI per capita weakly reduces replication in the 2001 data. When *telpen* and *polcon*, which are correlated with GNI per capita (0.80 and 0.64, respectively), are not included in the regression then the negative effect of *lngni01* is strongly significant. This is consistent with a pull perspective on knowledge—whereby knowledge is pulled into less developed countries because local firms have more to learn. In the second time period (2001, Table 2), source size and political risk have a positive, non-significant effect on replication.[3] Finally, country size (*lnpop*) and political risk (*polcon*) have a negative and non-significant effect on replication in the first time period but a generally positive and non-significant effect in 2001.

While model fit is not the focus of the analysis in this paper, a number of fit indicators are included in Tables 2 and 3. Model fit is acceptable using 2001 data in Table 2. Models 1–3 all have fit indices (incremental fit index (IFI or delta 2) and comparative fit index (CFI)) between 0.90 and 0.95. Using data from the first year of the relationship the fit is less good, but above 0.90 for the full model (Models 5–7 in Table 3).

Robustness

I analyzed the data under alternate approaches to estimation in order to gauge the robustness of the SEM results given the small sample and to explore alternative measures of performance. The results of these robustness checks are broadly consistent with the results of the hypothesized model. Time in the relationship increases adaptation in all specifications. Measures of discrete knowledge increase adaptation in most specifications. Replication and adaptation contribute to knowledge transfer in all specifications, while knowledge transfer leads to performance improvements for measures that emphasize short-term improvement, that is, in the year following transfer. For measures of performance improvement over the length of the relationship, I find knowledge transfer has no effect. So, while the results are broadly consistent with the hypotheses in the paper, some interesting nuances emerge from these analyses.

[2] In an alternative specification, I modeled selection at the level of knowledge transfer, which led to results consistent with those in Model 7, though the selection effect was not significant in this specification. In this specification, the relationship between knowledge transfer and performance becomes non-significant.

[3] Except in the OLS analysis, where *lnsrcsubs* has a significant, positive effect on replication.

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In particular, OLS analysis is less sensitive to the small-sample estimation issues that might arise in the SEM method used as the primary analysis because OLS approaches asymptotic behavior more quickly than maximum likelihood estimation (used in SEM). Table 4 shows the results of OLS analysis of each component (equation) within the full SEM model for Model 3 and Model 6 (Tables 2 and 3). In these models, the latent variables are treated as composite indexes—averages of indicator variables from the survey—so the models do not account for measurement error in estimating the variables of replication, adaptation, and knowledge transfer. The results of these individual regressions closely match those reported in the SEM analysis (Tables 2 and 3). The main difference is in the OLS analysis for the initial year, where the variables *telpen_i, cell*, and *new* have weak or no significant effect on adaptation, which could arise because measurement error is a larger concern in data requiring significant historical recall on the part of survey respondents.[4] Together, the OLS regressions suggest that the SEM results presented in the tables do not arise because of errors in estimation from the maximum likelihood estimation technique.

In the final robustness analysis, I explored alternative measures of performance. The relationship between knowledge transfer and performance remains significant for alternative short-term performance measures, but not for long-term measures. Growth in subscriber base is a very important metric for telecom firms, especially in emerging markets where they face a pent-up demand from consumers. When Model 7 uses growth in subscribers from year 1 to year 2 in place of the efficiency performance measure, the relationship between knowledge transfer and performance is positive and significant at the 0.05 level. When I substitute measures of performance improvement over the course of the relationship (first year until 2001), however, there is not a significant relationship between knowledge transfer and performance improvements. These long-term measures include efficiency and growth measures from public reports as well as self-reported improvements in five categories: service quality, efficiency, growth, innovation, and profitability. The lack of significance for long-term performance improvements suggests that the value of knowledge depreciates quickly (Argote, 1999; Darr *et al*., 1995). Knowledge has an impact one year after transfer, but the effect does not appear to lead to compounding improvements over the following years.

Summary

Overall, the results are consistent with the theoretical arguments laid out in the paper. Adaptation and replication are distinct transfer mechanisms that firms use simultaneously when transferring knowledge. Both contribute to transfer, which leads to improved efficiency. Adaptation rises with time, suggesting that time within the relationship is an important source of understanding. Replication does not rise when knowledge is more discrete, though adaptation does fall. Finally, the effect of governance on knowledge transfer changes over the course of the relationship. The source firm's ownership of the receiving firm does not affect transfer in the first year of the relationship, though later both replication and adaptation rise when source ownership is higher.

CONCLUSION

This paper contributes to our theory of organizational knowledge by bringing together two streams of research that have emphasized different aspects of knowledge: context dependence and causal ambiguity. The implicit assumption of these streams has been that replication and adaptation are mutually exclusive approaches to transfer. In this study, I find that the actions of firms transferring knowledge are consistent with the theory that knowledge is simultaneously context dependent and causally ambiguous. Firms replicate more when organizational knowledge is ambiguous and must be copied exactly, and firms adapt more when organizational knowledge depends on context and must be modified for the new setting. I define replication and adaptation as effort towards a goal, which opens the possibility that firms replicate and adapt simultaneously, and I find that they frequently do. In sum, I find that replication and

[4] Table 4 shows the following minor discrepancies with the SEM analysis. In two cases, variables (*telpen_i* and *cell*) in the initial year lose a significant impact on adaptation, presumably because of higher measurement error with longer recall. In three cases, variables (*firstown, cell, template*) that are not significantly different from zero change sign in the OLS results. Finally, three non-significant relationships between replication and other variables (*telpen_i, cell, lnsrcsubs*) in the SEM analysis gain weak significance in the OLS.

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adaptation vary separately, are used jointly, and contribute significantly to knowledge transfer.

This study is just a first step in developing these insights about knowledge. Any conclusions must be tempered by our understanding of the study's limits. The study's small sample size raises the question of whether the findings would be replicated in another study. Since SEM makes heavy demands of small samples, it is possible that the relationships between variables in this study might not represent the true asymptotic values of the parameters. Yet, the robustness analysis with OLS, which requires fewer observations, finds a similar pattern of relationships, mitigating this concern. Similarly, response bias could skew the results if this is an unrepresentative sample. Comparing our sample to the population of relationships, however, uncovers only small differences between them. Finally, the power of a test depends on the size of the effect, so this study has less power to determine the significance of small effects than large ones. It is likely that another study with a larger sample would find some of the non-significant parameters to be significant, though likely smaller than the relationships discussed in this paper.

In addition, the empirical setting raises two questions about how the results would generalize to other firms. As service firms, the companies in the study interact with the environment throughout their operations. In contrast, manufacturing firms can buffer some of their operations within facilities where there is less interaction with outside actors (Thompson, 1967). With careful buffering, the need for adaptation may be less than in service firms, and the effectiveness of replication may be increased. Service firms represent an interesting setting to study knowledge that is embodied in the routines of the firm, but it remains an empirical question if these results will generalize to settings where firms can buffer more of their core operations. Another limitation is that the study uses reports from the receiving partner to represent the policies of the transfer relationship. The relationship includes a source partner as well, and it is possible that the source's actions differ significantly from those of the receiver. Responses from receiving units suggest that source firm replication is correlated almost 0.9 with the receiving unit and source firm adaptation is correlated nearly 0.6 with receiving unit adaptation, but this study still lacks the source unit's perspective and the impact of its actions on transfer and performance.

Finally, some of the design choices in the study limit the extent to which we can distinguish the underlying mechanisms and compare alternative approaches to knowledge transfer. While I predict and find that firms are engaged in both replication and adaptation at the level of the relationship, this study cannot rule out the possibility that at some sufficiently fine-grained level of individual practice firms only employ one or the other transfer mechanism. The logic developed here suggests that even at a fine-grained level organizational knowledge is less like discrete atoms than like gears in a machine, which must be adapted to work together in a new setting. Future research will be needed, however, to explore how firms balance, combine, and trade off between replication and adaptation at the level of an individual practice. Similarly, the measurement of replication and adaptation as sustained practices over a year of the transfer relationship means that this study cannot distinguish fine-grained differences in the timing of the two activities. Szulanski's (2003) stage model of transfer includes four stages of transfer—initiation, implementation, ramp-up, and integration—and Szulanski and Winter (2002) recommend that adaptation should only occur after implementation. I find that, in the first year of the relationship, greater investment in adaptation leads to more knowledge transfer. While the theory developed here suggests that interdependent knowledge could not be implemented without some adaptation, this study cannot rule out the possibility that the adaptation reported in the first year occurs entirely after the actual implementation of new practices.

Despite these limitations, a number of interesting results emerge from the study that can help us develop our theory of organizational knowledge and suggest new paths for research. Adaptation emerges from the study as the primary tool by which firms calibrate transfer to a particular situation. When firms transfer more discrete knowledge to units in cellular markets, they adapt less because there are fewer connections. Firms adapt more when they possess understanding of the connections between knowledge and its environment. The finding that firms are quite active in managing the levels of adaptation to fit these contingencies suggests that adaptation deserves a central role in our theories of organizational knowledge.

That we have much more to learn about adaptation is suggested by two surprising results: when receiving units are newly founded they increase

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adaptation, but when source firms have prior experience with transfer they do not shift adaptation. Understanding is not something typically associated with organizations, but I propose that organizations possess understanding when they can predict how a given practice will interact with other elements of the organization and environment. One respondent from a source firm pointed to the management of interacting practices as an essential aspect of transfer: 'Some organizations are very good at [managing] the individual slices, but they do not have a good idea of how those slices fit together ... [my company] used to move people around and we developed a good feel for how the pieces fit together, which is not typical elsewhere.' Understanding interconnected knowledge might well contribute to recombination and innovation within firms (Teece, Pisano, and Shuen, 1997; Winter, 2003). A valuable future project would be to study how firms build understanding and where it must reside to be useful for knowledge transfer or recombination.

I find that knowledge transfer has a measurable impact on firm performance the year after knowledge is transferred. This effect is weak, but robust across several measures of performance, and it is larger when the model accounts for selection bias. In addition, the results are likely to understate the impact of transfer on performance since they do not include simultaneous transfer and performance improvements in the same year. However, the knowledge acquired by the receiving unit appears to depreciate rapidly, since there is no long-term performance impact from knowledge transfer in the first year of the relationship. The finding that knowledge in organizations depreciates at a fairly rapid pace also dovetails with other recent research (Argote, 1999; Darr *et al*., 1995). Our evolutionary theories of the firm need to be extended to explain the friction that keeps successful early transfer from leading to later transfer, and empirical studies need to examine the mechanisms that lead to rapid depreciation of knowledge.

From an evolutionary perspective, the picture of multinational firms that emerges from the study is of large firms evolving and changing as they move to new contexts rather than replicating uniform practices around the world. Thus, one mechanism of change for firms might be to expand to new environments where existing routines will require adaptation. From an evolutionary perspective, the study suggests an important question: when will the process of adaptation generate knowledge that firms carry back to their core operations and what firm policies will facilitate this knowledge creation and transfer?

In addition, the appropriate governance of knowledge transfer appears to vary over the relationship. Consistent with the transaction–cost perspective on the mitigation of hazards in knowledge transfer (Oxley, 1999), source ownership has a sizeable and significant impact on replication and adaptation later in the relationship. In the first year, however, ownership does not have a significant effect on investments in knowledge transfer. These results suggest that governance models for knowledge transfer need to incorporate the stage of relationship as a contingent factor shaping the choice of ownership.

While replication is clearly an important mechanism for knowledge transfer, this study suggests more about which factors *do not* lead to higher replication than those which do. Variables representing prior experience of the source firm and the level of discreteness of the knowledge have negligible impacts on replication. Some other factors, such as country development and source size, have large but non-significant effects, which might be significant in larger samples. Still, most of the contingencies for replication explored in this study appear to have less influence on replication than on adaptation. Perhaps replication is calibrated to the level of ambiguity in the targeted knowledge. In that case, future studies at the level of individual practices might explain the contingent nature of replication by measuring the relative causal ambiguity of different practices.[5] Some of the contingencies that drive replication may also be the factors that lead firms to enter knowledge transfer relationships. In this case, the decision to replicate may be tightly bound with the decision to transfer knowledge, after which adaptation is calibrated to the context. This suggests an alternative, multilevel model, in which adaptation increases the effectiveness of replication when knowledge is less discrete or understanding is greater. Such a model is beyond the possibilities of these data, but might

[5] One would expect, however, that practices would become less ambiguous as firms gained experience transferring them to new locations, but prior transfer has a negligible effect on replication in the study. Still, this could arise if causal ambiguity is so deep that it is not reduced through repeated transfer, which is the implicit assumption behind Intel's 'Copy Exactly!' policy (McDonald, 1998).

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be fruitful for future exploration. In the final analysis, there remains unexplained variance in replication, which awaits explanation as we develop our understanding of organizational knowledge.

When firms set out to transfer knowledge, the theory and empirical analysis in this paper suggest they must assess the nature of the knowledge to be transferred. Firms need to differentiate between ambiguous knowledge, which must be copied exactly, and knowledge intertwined with the environment, which requires modification. While exact copying of knowledge is difficult in new settings, effort invested in copying will significantly increase the transfer of valuable knowledge even if perfect copying is not achieved. In addition, the interdependent nature of knowledge means that firms will need to identify the interfaces between ambiguous knowledge and the context to target them for adaptation. Understanding the connections between knowledge, the organization, and its environment takes substantial experience in a specific relationship, but it can improve knowledge transfer and may create capabilities that are useful in other parts of the firm.

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APPENDIX 1: DESCRIPTIVE STATISTICS

	Variable	Description	Range	Mean	S.D.
(1)	*b1*	Knowledge transfer survey item 2001 (Table 1)	1–5	3.47	1.27
(2)	*b2*	Knowledge transfer survey item 2001 (Table 1)	1–5	3.32	1.38
(3)	*b3*	Knowledge transfer survey item 2001 (Table 1)	1–5	3.38	1.14
(4)	*c1*	Replication survey item 2001 (Table 1)	1–5	2.65	1.12
(5)	*c5*	Replication survey item 2001 (Table 1)	1–5	2.38	1.09
(6)	*c6*	Replication survey item 2001 (Table 1)	1–5	1.83	0.89
(7)	*c7*	Replication survey item 2001 (Table 1)	1–5	2.20	1.02
(8)	*e1*	Adaptation survey item 2001 (Table 1)	1–5	3.50	1.14
(9)	*e4*	Adaptation survey item 2001 (Table 1)	1–5	3.90	1.10
(10)	*e5*	Adaptation survey item 2001 (Table 1)	1–5	2.80	1.10
(11)	*e6*	Adaptation survey item 2001 (Table 1)	1–5	3.43	1.28
(12)	*pb1*	Knowledge transfer survey item initial year (Table 1)	1–5	3.88	1.10
(13)	*pb2*	Knowledge transfer survey item initial year (Table 1)	1–5	3.64	1.32
(14)	*pb3*	Knowledge transfer survey item initial year (Table 1)	1–5	3.51	1.25
(15)	*pc1*	Replication survey item initial year (Table 1)	1–5	3.02	1.14
(16)	*pc5*	Replication survey item initial year (Table 1)	1–5	2.71	1.22
(17)	*pc6*	Replication survey item initial year (Table 1)	1–5	2.25	1.20

(*continued overleaf*)

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APPENDIX 1 (*Continued*)

	Variable	Description	Range	Mean	S.D.
(18)	*pc7*	Replication survey item initial year (Table 1)	1–5	2.47	1.15
(19)	*pe1*	Adaptation survey item initial year (Table 1)	1–5	3.27	1.06
(20)	*pe4*	Adaptation survey item initial year (Table 1)	1–5	3.47	1.06
(21)	*pe5*	Adaptation survey item initial year (Table 1)	1–5	2.78	1.10
(22)	*pe6*	Adaptation survey item initial year (Table 1)	1–5	3.08	1.21
(23)	*edelt12*	Percentage change in subscribers/employee from year 1 to year 2	−0.33–6.76	0.70	1.25
(24)	*time*	Years since beginning of relationship	0–12	4.77	3.33
(25)	*year*	First year of relationship	1989–2001	1996.23	3.33
(26)	*new*	1 = Receiving firm founded initial year of relationship 0 = Receiving firm founded before relationship	0–1	0.47	0.50
(27)	*template*	1 = Source firm has home country operation 0 = Source firm has no home country operation	0–1	0.85	0.36
(28)	*cell*	1 = Receiving firm operates only in cellular markets 0 = Receiving firm operates in fixed service mkts	0–1	0.52	0.50
(29)	*curr_own*	Ownership stake of source firm, 2001	7–100	50.37	23.63
(30)	*first_own*	Ownership stake of source firm, initial year	6–100	41.55	22.81
(31)	*telpen01*	Telephones per 100 inhabitants, country 2001	0.20–90.71	23.65	19.45
(32)	*polcon*	Political risk 2001	0.00–0.78	0.36	0.22
(33)	*telpen_i*	Telephones per 100 inhabitants, country initial year	0.20–90.71	23.52	19.44
(34)	*polcon_i*	Political risk initial year	0.00–0.78	0.36	0.22
(35)	*lngdp_i*	Log(e) gdp per capita, initial year	5.72–10.47	8.05	1.14
(36)	*lnpop_i*	Log(e) population, country initial year	−2.81–5.10	2.55	1.53
(37)	*lnpop01*	Log(e) of population, country 2001	−2.81–5.15	2.54	1.57
(38)	*lngni01*	Log(e) of gross national income, 2001	5.56–10.55	8.18	1.10
(39)	*lnsrcsubs*	Log(e) of source firm subscribers, 2001	10.52–18.78	17.11	1.63
(40)	*lnrecsubs*	Log(e) of receiving firm subscribers, 2001	7.94–16.91	13.22	2.10
(41)	*scountries*	Count of countries where source firm provides telecom services	1–52	17.98	12.88
(42)	*srelat*	Number of source firm relationships within same country as receiving firm	1–8	2.38	2.07

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APPENDIX 2: CORRELATION MATRIX (OBSERVED VARIABLES)

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1)	*b1*	1.00																	
(2)	*b2*	0.96	1.00																
(3)	*b3*	0.75	0.73	1.00															
(4)	*c1*	0.46	0.37	0.42	1.00														
(5)	*c5*	0.43	0.38	0.56	0.64	1.00													
(6)	*c6*	0.46	0.42	0.58	0.48	0.77	1.00												
(7)	*c7*	0.44	0.42	0.52	0.63	0.68	0.77	1.00											
(8)	*e1*	0.34	0.30	0.28	−0.08	−0.02	−0.03	0.04	1.00										
(9)	*e4*	0.40	0.39	0.43	0.07	0.11	0.07	0.12	0.70	1.00									
(10)	*e5*	0.20	0.16	0.20	0.11	0.11	0.16	0.19	0.57	0.56	1.00								
(11)	*e6*	0.53	0.55	0.58	0.07	0.16	0.14	0.23	0.67	0.57	0.57	1.00							
(12)	*pb1*	0.54	0.51	0.39	0.13	0.23	0.22	0.21	0.42	0.42	0.09	0.49	1.00						
(13)	*pb2*	0.57	0.58	0.41	0.07	0.15	0.14	0.23	0.47	0.48	0.07	0.52	0.88	1.00					
(14)	*pb3*	0.33	0.29	0.50	0.14	0.29	0.19	0.32	0.39	0.39	0.14	0.46	0.71	0.76	1.00				
(15)	*pc1*	0.17	0.09	0.22	0.64	0.55	0.35	0.53	−0.09	−0.03	0.14	0.11	0.21	0.15	0.25	1.00			
(16)	*pc5*	0.09	0.03	0.33	0.35	0.66	0.49	0.53	0.12	0.19	0.17	0.21	0.30	0.26	0.47	0.52	1.00		
(17)	*pc6*	0.20	0.13	0.42	0.25	0.57	0.71	0.57	0.07	0.16	0.12	0.12	0.33	0.33	0.39	0.43	0.78	1.00	
(18)	*pc7*	0.11	0.12	0.25	0.39	0.57	0.54	0.65	0.05	0.24	0.14	0.21	0.29	0.29	0.34	0.63	0.74	0.70	1.00
(19)	*pe1*	0.18	0.11	0.06	−0.01	−0.13	−0.14	−0.04	0.51	0.37	0.40	0.44	0.50	0.47	0.31	0.16	0.09	0.07	0.08
(20)	*pe4*	0.26	0.22	0.21	0.16	0.04	−0.06	0.00	0.22	0.47	0.24	0.35	0.42	0.48	0.39	0.20	0.00	0.00	0.12
(21)	*pe5*	0.01	0.00	0.12	0.17	0.17	0.17	0.13	0.29	0.48	0.63	0.30	0.15	0.16	0.12	0.27	0.23	0.27	0.38
(22)	*pe6*	0.34	0.33	0.22	0.13	−0.03	−0.08	0.04	0.44	0.33	0.37	0.59	0.39	0.42	0.25	0.21	−0.01	−0.10	0.00
(23)	*edelt12*	0.12	0.16	0.13	0.19	0.09	0.11	0.27	0.00	−0.04	−0.01	0.01	0.20	0.29	0.23	0.10	0.07	0.10	0.23
(24)	*time*	0.13	0.10	0.19	−0.05	0.13	0.20	0.14	0.33	0.35	0.28	0.29	0.27	0.24	0.26	0.21	0.26	0.36	0.26

APPENDIX 2: (*Continued*)

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(25)	*year*	−0.13	−0.10	−0.19	0.05	−0.13	−0.20	−0.14	−0.33	−0.35	−0.28	−0.29	−0.27	−0.24	−0.26	−0.21	−0.26	−0.36	−0.26
(26)	*new*	0.10	0.09	0.01	0.04	−0.04	0.10	0.06	0.24	0.16	0.09	0.06	0.23	0.40	0.09	0.09	0.14	0.35	0.10
(27)	*template*	−0.18	−0.18	−0.25	−0.21	−0.25	−0.22	0.18	−0.05	−0.14	0.18	0.07	−0.01	−0.02	0.07	−0.13	−0.03	−0.23	0.05
(28)	*cell*	0.24	0.22	0.15	0.31	0.06	0.12	0.06	0.06	−0.06	−0.18	−0.08	0.22	0.34	0.11	0.23	0.07	0.21	−0.01
(29)	*curr_own*	0.53	0.50	0.31	0.30	0.27	0.07	0.14	0.34	0.25	0.26	0.34	0.26	0.30	0.14	0.24	0.04	0.02	0.12
(30)	*first_own*	0.38	0.37	0.36	0.34	0.19	0.28	0.21	0.22	0.15	0.08	0.16	−0.11	−0.02	−0.24	−0.02	0.02	0.15	0.02
(31)	*telpen01*	0.10	0.08	−0.03	−0.22	−0.37	−0.34	−0.29	0.21	0.17	−0.10	0.09	0.19	0.17	−0.02	−0.42	−0.16	−0.23	−0.29
(32)	*polcon*	0.11	0.15	0.32	−0.08	−0.07	0.05	0.06	0.21	0.22	0.15	0.26	0.07	0.13	0.24	−0.22	0.01	0.03	−0.10
(33)	*telpen_i*	0.10	0.08	−0.03	−0.22	−0.37	−0.34	−0.29	0.21	0.17	−0.10	0.09	0.19	0.17	−0.02	−0.42	−0.16	−0.23	−0.30
(34)	*polcon_i*	0.11	0.15	0.32	−0.08	−0.07	0.05	0.06	0.21	0.22	0.15	0.26	0.07	0.13	0.24	−0.22	0.01	0.04	−0.10
(35)	*lngdp_i*	0.15	0.10	−0.01	−0.04	−0.21	−0.25	−0.18	0.21	0.07	−0.11	−0.01	0.10	0.17	0.11	−0.31	−0.17	−0.20	−0.20
(36)	*lnpop_i*	0.11	0.16	0.01	0.01	0.10	0.08	0.12	0.13	−0.02	0.13	−0.04	0.05	0.24	0.23	0.03	−0.08	0.05	0.12
(37)	*lnpop01*	0.09	0.13	−0.02	0.00	0.15	0.12	0.15	0.12	−0.01	0.12	−0.05	0.02	0.21	0.18	0.04	−0.02	0.09	0.15
(38)	*lngni01*	0.15	0.11	0.02	−0.11	−0.23	−0.26	−0.21	0.40	0.21	−0.04	0.16	0.21	0.22	0.13	−0.31	−0.15	−0.21	−0.23
(39)	*lnsrcsubs*	0.15	0.10	0.18	0.10	0.15	0.18	0.26	0.14	0.14	0.11	0.27	0.18	0.09	0.20	−0.04	0.17	0.17	0.22
(40)	*lnrecsubs*	0.24	0.19	0.26	0.23	0.22	0.19	0.28	0.28	0.11	0.40	0.28	0.13	0.06	0.17	0.20	0.18	0.09	0.21
(41)	*scountries*	0.26	0.28	0.23	0.08	0.20	0.00	0.17	0.25	0.18	0.08	0.33	0.11	0.18	0.15	0.14	0.01	−0.03	0.14
(42)	*srelat*	−0.06	0.00	−0.11	−0.21	0.02	−0.13	−0.04	0.11	0.13	0.11	0.00	−0.09	0.02	0.02	0.00	−0.18	−0.20	−0.06
		(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)
(19)	*pe1*	1.00																	
(20)	*pe4*	0.67	1.00																
(21)	*pe5*	0.54	0.47	1.00															
(22)	*pe6*	0.63	0.59	0.35	1.00														
(23)	*edelt12*	0.04	0.02	0.10	0.06	1.00													
(24)	*time*	0.15	0.08	0.12	−0.02	−0.05	1.00												
(25)	*year*	−0.15	−0.08	−0.12	0.02	0.05	−1.00	1.00											
(26)	*new*	0.34	0.22	0.11	0.18	0.39	0.20	−0.20	1.00										
(27)	*template*	0.05	−0.06	0.00	0.15	−0.03	−0.31	0.31	−0.15	1.00									
(28)	*cell*	0.05	−0.01	−0.07	0.16	0.43	0.00	0.00	0.66	−0.18	1.00								

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(29)	*curr_own*	0.26	0.23	0.19	0.23	−0.15	0.13	−0.13	0.11	−0.34	0.17	1.00						
(30)	*first_own*	0.07	−0.06	−0.02	0.07	0.12	−0.10	0.10	0.32	−0.32	0.49	0.32	1.00					
(31)	*telpen01*	0.39	0.12	0.02	0.22	0.16	−0.18	0.18	0.18	0.19	0.15	0.06	0.23	1.00				
(32)	*polcon*	0.05	−0.04	0.11	0.10	0.19	0.19	−0.19	0.02	0.14	−0.02	−0.04	0.05	0.39	1.00			
(33)	*telpen_i*	0.39	0.12	0.01	0.22	0.16	−0.18	0.18	0.18	0.19	0.15	0.06	0.23	1.00	0.39	1.00		
(34)	*polcon_i*	0.05	−0.04	0.11	0.10	0.19	0.19	−0.19	0.02	0.14	−0.02	−0.04	0.05	0.39	1.00	0.39	1.00	
(35)	*lngdp_i*	0.23	0.11	0.03	0.22	0.19	−0.32	0.32	0.08	0.29	0.09	0.21	0.08	0.74	0.39	0.74	0.39	1.00
(36)	*lnpop_i*	−0.10	0.11	0.17	0.14	0.23	−0.12	0.12	0.12	−0.02	0.12	0.11	−0.13	−0.31	−0.24	−0.31	−0.24	0.19	1.00
(37)	*lnpop01*	−0.12	0.09	0.16	0.11	0.24	−0.06	0.06	0.15	−0.03	0.08	0.09	−0.13	−0.34	−0.25	−0.34	−0.25	0.14	0.98
(38)	*lngni01*	0.30	0.10	0.02	0.32	0.20	−0.06	0.06	0.14	0.23	0.11	0.19	0.07	0.80	0.50	0.80	0.50	0.90	0.02
(39)	*lnsrcsubs*	0.12	0.10	0.10	0.11	−0.09	0.10	−0.10	−0.05	0.33	−0.19	0.03	−0.06	−0.01	0.06	−0.01	0.06	0.18	0.21
(40)	*lnrecsubs*	0.03	−0.16	0.24	0.29	0.17	−0.08	0.08	−0.14	0.11	0.22	0.23	0.19	0.05	0.11	0.05	0.11	0.16	0.23
(41)	*scountries*	−0.01	0.08	−0.03	0.18	−0.09	0.11	−0.11	−0.03	0.00	−0.03	0.43	0.03	−0.17	0.06	−0.17	0.06	0.09	0.37
(42)	*srelat*	−0.06	0.11	0.04	−0.01	−0.24	0.18	−0.18	−0.06	0.12	−0.19	0.37	−0.27	−0.16	0.10	−0.16	0.10	0.15	0.35

APPENDIX 2: (*Continued*)

		(37)	(38)	(39)	(40)	(41)	(42)
(37)	*lnpop01*	1.00					
(38)	*lngni01*	−0.01	1.00				
(39)	*lnsrcsubs*	0.27	0.13	1.00			
(40)	*lnrecsubs*	0.21	0.18	0.19	1.00		
(41)	*scountries*	0.41	0.08	0.56	0.29	1.00	
(42)	*srelat*	0.37	0.14	0.22	−0.02	0.63	1.00