Does Distance Matter?

The Influence of ICT on Bilateral Trade Flows

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ABSTRACT

Information and communication technology (ICT) has altered previous notions of distance and led to discussions in the popular press of the "death of distance." Geographic distance typically results in diminished trade flows between countries, but does ICT play a role in overcoming geographic distance? This article examines the key hypothesis that ICT reduces the cost associated with the conduct of international trade between distant countries. In this research, we examine bilateral trade flows and geographic distance data for 175 different countries. We use a gravitational model to determine if physical and cultural distance matters in how ICT affects bilateral trade flows. Our methodology involves the use of 14,511 country pairs, for which we can represent and evaluate the effects of our distance measures. We find that greater bilateral trade flows occur between countries with higher Internet use, suggesting that the presence of common digital infrastructure between countries will enhance their trade. We also found that ICT use has a more positive impact on bilateral trade flows between large economies than it does for smaller economies. Finally, ICT use by more distant trading partners appears to have a more positive impact on trade than it does on countries that are nearer to one another.

Keywords: Distance, digital divide, econometric analysis, economic geography, information and communication technology (ICT), international development, international trade, technology

> *My goal is to make the World Bank the first port of call when people need knowledge about development. By the year 2000, we will have in place a global communications system with computer links, videoconferencing, and interactive classrooms, affording our clients all around the world full access to our information bases – the end of geography as we at the World Bank have known it.*
>
> – James D. Wolfesohn, President, World Bank, Annual Address (1997)

INTRODUCTION

James Wolfesohn's statement portrays the impact that information and communication technology (ICT) will have on global development. Others have written that ICTs enable sharing of product knowledge and process expertise, irrespective of the geographic distance between the people involved. ICT alters notions of distance, which have remained constant for thousands of years. 150 years ago, a firm opening a trading relationship between the U.S. and India would have had to send agents thousands of miles to meet in person, exchange hand-written documents via expensive post with weeks of transit time over sea and land, and overcome language barriers. Transportation technologies like air travel, or the increased universality of English have decreased this distance, and ICTs such as phones and e-mail have made the conduct of trade easier. ICT has decreased the distance between countries like India and the U.S, even though our physical world is no different. Cairncross (1997) calls this the "death of distance:" various kinds of ICT make geographic distance obsolete.

Geographic distance has historically played a key role in international trade. According to Eaton and Kortum (2002), trade between countries diminishes with distance. A trade transaction cannot occur without a relationship, and the involved parties must overcome the distance between them. ICT can overcome the physical distance separating countries. Since ICT decreases coordination and transaction costs (Malone et al. 1987), trade flows should increase for countries in spite of the distance between them, due to the increasing impacts of ICT.

This research aims to analyze the empirical evidence on how ICT allows trading partners to overcome distance related effects. We examine large and small economies, and geographically close and distant countries. Previous studies have shown that technology (Dosi and Soete 1988, Fujita et al. 1999) and distance (Frankel and Rose 2002, Engel and Rogers 1996) affect trade flows, but the authors did not analyze technology and distance together. We propose a new *ICT-led trade cost reduction theory* to fill this gap and provide answers to policy-makers and senior managers with respect to the global digital divide. This research is interdisciplinary. As such, we borrow concepts from trade economics, regional geography and information systems (IS) research. Economic geographers require intimate knowledge of the relationship between distance and technology and its impacts. This is true for policy-makers who are contemplating government investments in ICT infrastructure, and entrepreneurs and foreign direct investors who hope to deploy their capital for the benefit of the firms they represent, as well as the good of the regional economies they target.

The problem is that poorer nations engage in less trade than richer countries, yet countries that engage in more trade benefit from higher gross domestic product (GDP). Often poorer countries have a greater "distance" – with geographic distance, and language, cultural and political barriers – to trading partners than the rich countries do. If ICT investments can help countries and economies to overcome these barriers, developing countries will be better able to increase bilateral trade with other countries, increasing their wealth over time.

The overarching research question in this study is whether ICT impacts the different kinds of distance that have traditionally moderated the extent to which trade flows develop and are observed over time. We ask: Does more ICT in a country support increased bilateral trade flows with its trade partners? Can we model ICT impacts as a gravitational force, to overcome the physical and cultural distances that constrain bilateral trade flows? Does ICT in larger economies have a greater effect on bilateral trade flows than in smaller economies? And does ICT have a greater effect on bilateral trade flows with distant or close countries? To answer, we explore theory from the *new economic geography* paradigm. This is associated with the Nobel Prize-winning economics research of Princeton economist, Paul Krugman (1991a, 1991b), and others in economics (e.g., Brakman et al. 2001, Fujita et al. 1999), as well as empirical works of authors in economics (Redding 2009) and IS (Forman et al. 2005, Kauffman and Kumar 2007).

The remainder of the paper is laid out as follows. §2 introduces the theoretical background and measurement approaches for distance measures and theory that we use. §3 discusses our hypotheses and the conceptual model for our theory. §4 presents the data and variables, and §5 discusses the estimation model we use. §6 presents the results of our empirical study. §7 concludes with contributions and some of this study's limitations.

2. THEORY AND MEASUREMENT

We begin by discussing distance theory and distance concepts, followed by transaction cost and trade factors theory, before we propose our own new theory.

2.1. Distance Theory and Measurement

To begin our discussion of *distance theory*, a term which we will use as a catch-all for the explanations that are available for a number of different kinds of "distance," we consider geographic, conceptual, and location-theoretic perspectives.

Geographic Distance. People think of "distance" between two places in *physical distance* or *geographic distance* terms. For geographic distance, we consider the number of miles separating two countries or the time it takes to travel between them. These measures of distance have implications in the economic marketplace. Previous researchers concluded that for every 1% increase in physical distance between two countries, trade flows decrease by 1.1% (Frankel and Rose 2002). Other research suggested that the amount of trade that takes place between countries 5,000 miles apart is only 20% of the amount that would be predicted to take place if the same countries were 1,000 miles apart (Ghemawat 2001).

Physical measures of distance are not limited to geographic interpretations (e.g., latitude, kilometers, etc.). Frankel and Rose (2002) used other physical distance measures in their research on trade. First, a common border between two countries can account for as much as an 80% increase in trade flows over expected bilateral levels. Engel and Rogers (1996) have shown the effect of a common border on distance. They showed that consumer price variation is higher for equidistant cities across an international border than for equidistant cities within the same country. Second, a country's access to an ocean decreases its effective distance to other countries, and can account for 50% increase in bilateral trade flows. A third measure of distance, physical country size, has the effect of decreasing trade flows as country size increases. A large country size results in an increased distance to transport goods from a border or shore to the interior of a large country – for example, countries such as the U.S., Russia, Brazil or Australia, which have proportions similar to a continent.

Non-Geographic and Conceptual Measures of Distance. It is not sufficient to define distance between individuals, firms, or countries by physical measures alone. Frankel and Rose (2000) note that traditional country portfolio analysis needs to be informed by many different dimensions of distance, which are likely to have different impacts on opportunities in foreign markets. Ghemawat (2001) developed a framework to identify different measures of distance and stated that non-geographic measures can be categorized by cultural, administrative, and economic measures. Another way to distinguish non-geographic measures of distance that seems useful is to consider economic and non-economic distances.

Many studies have defined economic measures for representing distance. Conley and Ligon (2002) defined *economic distance* using United Parcel Service (UPS) distance and airfare distance, which represent the costs of shipping a package between the capital cities of two countries and the economy airfare between different airport hubs. Distance can also be measured institutionally. Since greater development occurs in economies that have institutions, two economies without viable economic institutions (e.g., a central bank or a department of commerce) can be considered to be more distant in economic terms than two economies that have such institutions (Acemoglu et al. 2005). A common currency between two countries also can decrease the economic distance between two countries. In some cases, this can increase international trade by 340% compared to two countries that have different currencies (Frankel and Rose 2002). Access to markets and the proximity to sources of supply are consistent with the idea of economic distance. Redding and Venables (2004) found this to be explanatory of global wealth variation. These things at times can discourage firms from outsourcing production to low-wage countries, especially if the low-wage country is more physically distant from markets and suppliers.

Non-physical distance can also be measured in non-economic terms. Colony relationships, language and religion similarity can define *cultural distance*, for example. Ethnic and occupational distances between Chicago communities were able to explain spatial patterns of unemployment in the 1980s and 1990s (Conley and Topa 2002). *Communication distance* is another non-economic distance measure, defined in terms of the method of communication between two parties. People who communicate in person will be closer than others who communicate by phone, yet closer than others who communicate only by mail (Petersen and Rajan 2002). Other non-physical and non-economic measures of distance include search cost distance, control and management distance, social distance, political distance, ideological distance, and psychological distance (Isard et al. 1998, Venables 2001).

Location-Theoretic Perspectives. Other aspects of location cannot be easily categorized as measures of distance, though they are meaningful in shaping a complete view of the role of location and how ICT affect its. We refer to these other facets as *location-theoretic perspectives.* The first of these, *spillover theory*, includes the studies of benefits from any positive externality that results from purposeful investment in technological innovation or development, according to Weyant and Olavson (1999). Foreign direct investment (FDI) drives technology spillovers through human capital sharing, supplier-customer relationships, or simply by prompting entrepreneurs and managers to closely observe the behavior and activities of foreign firms (Liu 2002). Walz (1997) found that when firms make R&D investments in a developed country while using production inputs from lower-cost developing countries, knowledge spillovers occur from the developed to the developing country. Watanabe et al. (2001) noted that such spillovers are increasing, and international competitiveness for nations and firms has been radically affected.

With respect to Internet technology adoption, two contradictory spillover beliefs exist (Forman et al. 2005). Since the Internet requires greater infrastructure and support, Internet use is expected to be greater in cities where infrastructure is available. The contradictory belief argues that since the Internet reduces coordination costs, the importance of distance is lessened and greater Internet use will be evident in rural areas.

2.2. Transaction Costs and International Trade Theory

Transaction cost theory views the cost of a good as the all-in costs of economic exchange. They include search for information, bargaining, policy and enforcement, and coordination costs. All trade involves transaction costs, but since ICT reduces these costs, trade should increase for countries that make more ICT investments.

Countries with higher *competitiveness* via the productivity of their available resources will tend to engage in more trade (Klemperer 1995). The World Economic Forum publishes an annual report assigning 134 countries a numeric *Competitiveness Index* based on dozens of variables, seven of which relate to *technological readiness* (Kauffman and Kumar 2008). The indices represent the attractiveness of countries to global trading partners. The consensus of the research on competitiveness is that greater investment in technological infrastructure boosts trade (Porter and Schwab 2008).

Another perspective is the *new trade theory* of Markusen and Venables (1998). It states that more trade will occur between countries with similar factor endowments and productivity. We extend this to argue that more trade will occur between countries with high ICT levels.

2.3. An ICT-Led Trade Cost Reduction Theory: Basic Elements

Trade flows decrease with distance. Transaction cost theory suggests that overcoming distance is costly. There are four reasons why (Venables 2001). Search costs increase with distance. Shipping costs increase with distance too. Management and control costs increase with distance. And time costs associated with shipping and communicating with trading partners are affected by distance. See Table 1. So more trade should occur between countries with higher ICT penetration levels, since trading with these partners should be less costly. We refer to this as *ICT-led trade cost reduction theory*. The outcome will still be moderated by distance though.

Table 1. The Effect of ICT on Distance Cost

TYPE	EFFECT OF IT
Search Cost	ICT-supported intermediation between buyers and sellers creates an e-marketplace that lowers buyer costs to acquire information about seller prices and produce offerings. This reduces buyer search cost inefficiency (Bakos 1997).
Management and Control Cost	Monitoring employees and trading partners ensures transactions can be performed electronically by the principal, reducing cost (Gurbaxani and Whang 1991).
Shipping Cost	ICT reduces coordination cost, which reduces shipping cost (Gurbaxani and Whang 1991). This reflects ICT-led reduces in supply chain management overall.
Time Cost	ICT supports communication at lower cost; the marginal cost of communicating at any greater distance is essentially zero (Cairncross 1997).

3. HYPOTHESES AND CONCEPTUAL MODEL

We next state our hypotheses and specify the conceptual model for our theory.

3.1. Hypotheses

There should be a relationship between bilateral trade flows, and Internet use in two different countries, based on our prior discussion of theory:

- **Hypothesis 1 (The Overall Internet Use Hypothesis).** *Larger bilateral trade flows will occur between countries with higher Internet use.*

ICT utilization in developed countries has a greater impact on trade flows than it does in developing countries, according to Dewan and Kraemer (2000), who posit that there are relevant complementarities that exist. Thus:

- **Hypothesis 2 (The Economy Size Internet Use Hypothesis)**. *Internet use will be associated with greater bilateral trade flows among larger economies than among smaller economies.*

Kauffman and Kumar (2007) hypothesized that Internet adoption is associated with the diminished importance of distance in the market linkages of technology industries. Therefore, the effect of the Internet and other ICTs will increase as distance increases. The final hypothesis deals with the effects of ICT on bilateral trade flows between countries at different distances:

- **Hypothesis 3 (The Distant Country-Pairs Internet Use Hypothesis).** *Internet use will be associated with higher bilateral trade flows in more distant country-pairs than in nearer country-pairs.*

3.2. Conceptual Model

We will use a conceptual model that is able to demonstrate the role of distance as a moderating variable, while we capture the main effects. A *moderating variable* is one that acts to influence the strength of the relationship between an independent variable and a dependent variable (Barron and Kenny 1986). In this case, distance will moderate the relationship between ICT and country-level trade flows. The conceptual model is given by:

$$Trade_{ij} = f\,(ICT_i, ICT_j, PhysicalDistance_{ij}, CulturalDistance_{ij}) \quad (1)$$

This states that the bilateral trade flow $Trade_{ij}$ between countries i and j is equal to a function of the ICT characteristics of country i (ICT_i) and country j (ICT_j), the physical distance ($PhysicalDistance_{ij}$) and cultural distance ($CulturalDistance_{ij}$) between the countries, and an error ε_{ij}.

A popular way to model this in the international trade and regional integration economics literature is through the use of a *gravity model* (e.g., Anderson 1979, Frankel and Rose 2002, Frankel and Wei 1998, Fratianni and Kang 2006, Skinner et al. 1999). The model is based on Newton's Law of Universal Gravitation. He stated that any two objects have attractive forces on each other, which are a function of the distance between them and their masses. Authors in trade and developmental economics, and political economy have modified this law to predict the effects that distance and population have on people, commodities trade, the exchange of ideas, and so on. Even though the gravity model was introduced fifty years ago, it has maintained its validity in predicting trade flows even with the more sophisticated spatial economic research that has developed over the past two decades (Porojan 2001).

Studies on trade flows that use this approach date back to the 1960s (Frankel 1997). The idea is that the greater the population or GDP, along with the shorter the distance between two places, the more will the migration of people, ideas, and trade be observed. For example, the gravity model can be used to show that even though the U.S. is closer to Haiti than Australia, proportionally greater trade is expected to occur with Australia, since the *gravitational pull* of Australia's large GDP will have a greater effect than Haiti's close proximity. The general form of the gravity model shows how trade flows between countries *i* and *j* ($TRADE_{ij}$) are equal to a constant *k* multiplied by the product of population or GDP of country *i* with country *j* (*POPULATION*) divided by the distance between countries *i* and *j* (*DISTANCE*):

$$TRADE_{ij} = k\,(POPULATION_i \cdot POPULATION_j) \,/\, DISTANCE_{ij} \qquad \textbf{The Gravity Model} \quad (2)$$

4. DATA AND VARIABLES

The 2005 cross-sectional data for this study are from multiple sources. Bilateral trade flows are from the U.N. Commodity Trade Statistics Database, which has country-level data dating from 1962 for an exhaustive list of countries. We collected imports and exports for all commodities for all home countries and their trade partners. This database distinguishes between a *reporting country,* which we refer to as the *home country* and is the first country listed in a *country-pair*, and the *partner country,* the second one listed. We obtained 42,650 bilateral trade flows.

The main effects variable reflects *ICT penetration*. We chose one variable to represent these constructs: Internet users per 100 population. Others variables we considered were highly correlated with the ICT variables, so we excluded them. The variables provide a broad cross-section of ICT penetration, since two ICTs are represented, and each has a different measure. Other research has used Internet usage to study aggregate-level outcomes (e.g., Madon 2000, Wallsten 2005, Chinn and Fairlie 2006). Telecommunications activities-related variables are also commonly used (Kauffman and Kumar 2008, Kauffman and Techatassanasoontorn 2005). We obtained Internet usage data from the U.N. Statistics Division.

The geodesic distance variables are from the French organization Centre D'Etudes Prospectives et D'Informations Internationales. We obtained 50,176 country-pairs along with twelve distance variables, and we use five here. *Geodesic distance* is the “great circle” distance between the most populous cities of a country-pair in kilometers. Other studies have used this same approach (Amiti and Wakelin 2003, Bergstrand 1985, Nitsch 2000). We recognize that bias may be introduced in the case of large countries. For example, while New York may be the largest city in the United States, the majority of trade between the U.S. and Japan occurs between the ports of Los Angeles and Tokyo, not New York and Tokyo. Given the size of the data set, it would be difficult to specify the “major port city” for each country specific to each country pair, which is why only one city is used to calculate the great circle distances for each country. The other four are dummy variables indicating a shared common border, language, colonizer or historical colonial link. Language commonality and colonizer relationships are controls for cultural distance.

Table 2. Variable Names and Descriptions

VARIABLE	DESCRIPTION	COMMENTS
TRADE	Exports + imports, home to partner country ($US mm)	Total bilateral trade
HOME_GDP	GDP for home country ($US millions)	Baseline for home country wealth
PTNR_GDP	GDP partner country ($US millions)	Baseline for partner country wealth
HOME_INET	Internet users/100 population, home country	Home country Internet infrastructure
PTNR_INET	Internet users/100 population, partner country	Partner country Internet infrastructure
DISTANCE	Distance between most populous cities (km)	Geodesic distance between countries
BORDERS	Common border	Binary (1 = has border, else 0)
COMLANG	Common official language	Binary (1 = common language, else 0)
COLONY	Current or historical colonial link	Binary (1 = colony, else 0)
COMCOL	Shared common colonizer	Binary (1 = common colonizer, else 0)

We considered control variables from research that used trade flows as the dependent variable (e.g., Srivastava and Green 1986, Helpman et al. 2008). Among them, the level of GDP[1] occurred very often. We collected 2005 GDP levels denominated in 2005 U.S. dollars for the countries in our data set from the U.N. Statistics Division. Three-digit International Standards Organization (ISO) country codes were used to uniquely designate a country's data across various sources. This permitted us to match the ISO codes, country-pairs and variables. Each observation in our final data set represented a country-pair, denoted by the three-digit ISO code for the reporting country (i.e., home country), followed by a hyphen and the three-digit ISO code for the partner country (e.g., "BRA-FRA" for Brazil and France). The variables in the data set for each country-pair are shown in Table 2. After dealing with missing data issues, the final data set consists of 14,511 country-pairs from 175 countries.[2] Tables 3 and 4 provide summary statistics and correlations for the variables.

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[1] An anonymous reviewer suggested replacing GDP in our model with GDP per capita as to test the effects of wealth instead of economy size. We attempted this approach, but it resulted in high pairwise correlation coefficients among the explanatory variables and collinearity issues. Because this was unacceptable, we retained only GDP in our model. In essence, there is already information regarding GDP per capital in our model, otherwise the pairwise correlation wouldn't have occurred.

[2] We deleted observations with missing values using the *listwise method* (Allison 2001); a country-pair was deleted if any variable had a missing value. Although this is problematic for small samples, our data set is large and so we had degrees of freedom to sacrifice without threatening the validity of our results (Olinsky et al. 2003). Omission of a country-pair mostly was due to unavailable ICT variables. Most deleted countries were too small or poor to collect ICT data. So the data are *missing not at random*. So

Table 3. Descriptive Statistics

VARIABLE	MEAN	STD. DEV.	MIN	MAX
TRADE	1,250	10,100	87	503,000
HOME_GDP	448,000	1,420,000	66.4	12,400,000
PTNR_GDP	401,000	1,350,000	66.4	12,400,000
HOME_INET	26.12	22.06	0.21	79.73
PTNR_INET	22.48	21.43	0.06	79.73
DISTANCE	6,996	4,443	56.62	19,812
BORDERS	0.27	0.16	0	1
COMLANG	0.16	0.37	0	1
COLONY	0.02	0.37	0	1
COMCOL	0.09	0.29	0	1
Note: All values of *TRADE* and *GDP* are denominated in millions of Year 2005 US$.				

Table 4. Correlation Matrix

	DISTANCE	*BORDERS*	*HOME_INET*	*PTNR_NET*	*COMLANG*	*COLONY*
BORDERS	-0.221***					
HOME_INET	0.023***	-0.053***				
PTNR_INET	0.017**	-0.030***	-0.075***			
COMLANG	-0.106***	0.124***	-0.081***	-0.047***		
COLONY	-0.036***	0.101***	0.047***	0.042***	0.179***	
COMCOL	-0.117***	0.070***	-0.136***	-0.084***	0.358***	-0.046***

5. ESTIMATION MODEL

We next lay out the functional form of the estimation model. There are many similar models in trade economics that showcase different kinds of variables. We provide some details here since the model will not be familiar to the IS research and SIG Global Development Workshop audiences. Limão and Venables (2001) describe the steps to transform the gravity model for estimation. The initial model is:

$$TRADE_{ij} = k \cdot POPULATION_i \cdot POPULATION_j \cdot (1/DISTANCEij) \cdot \eta_{ij} \quad (3)$$

The main differences from the base gravity model are the inclusion of 1 / $DISTANCE_{ij}$, which has been substituted for $DISTANCE_{ij}$ in the denominator of the fraction, and an error term η_{ij}. Taking logs yields the following function with additive, separable parameters:

$$\log(TRADE_{ij}) = \beta_0 + \beta_1 \log(POPULATION_i) + \beta_2 \log(POPULATION_j) + \beta_3 \log(DISTANCE_{ij}) + \log(\eta_{ij}) \quad (4)$$

β_0 replaces *k* as the constant, and $DISTANCE_{ij}$ replaces 1 / $DISTANCE_{ij}$. The effect is to allow the parameter estimate to be negative, since trade decreases with distance. Critics of this

though we removed small and poor countries, our data still contain small and poor countries such as Kiribati, Dominica, and Samoa, among others, diminishing our concerns.

approach note that the model cannot estimate $TRADE_{ij}$ to be zero. Our data do not include observations for which bilateral trade is zero though, so we are unconcerned. Santos Silva et al. (2006) note that estimating the log-linear model using ordinary least squares (OLS) may lead to biased estimates. They suggest a multiplicative form that can be estimated with a Poisson pseudo-maximum likelihood estimator. This bias is only evident in the presence of heteroskedasticity though. So we conducted a Breusch and Pagan (1979) test for heteroskedasticity, or non-zero error variances. The results confirmed the constant variance assumption of OLS. OLS estimation also requires normality of the model variables and the complete sample. We applied the Shapiro and Wilk (1965) *W* test for normality, with visual inspection of kernel density and standardized normal probability plots, and confirmed that the assumption holds (Mukherjee et al. 1998).

We extend the gravity model to include variables of interest related to the impacts of ICT and distance.[3] We proxied for ICT penetration with Internet use for Internet technologies. We also included a variable to capture another aspect of the distance between countries, with a dummy variable indicating whether the countries share a common border. We further supplemented the physical distance variables with three cultural distance variables: shared official language, current or historic colonial link, and shared common colonizer. The parameters for dummy variables are not logged, in accordance with Limao and Venables (2001). An alternative is to log all variables and covert the 0s and 1s in the data set to 1 and *e*, yielding the numerical equivalent of the desired 0s and 1s. The resulting equation is:

$$\begin{aligned} \log(TRADE_{ij}) = \beta_0 &+ \beta_1 \log(HOME\_NET_i) + \beta_2 \log(PTNR\_NET_j) \\ &+ \beta_3 \log(HOME\_GDP_i) + \beta_4 \log(PTNR\_GDP_j) \\ &+ \beta_5 \log(DISTANCE_{ij}) \\ &+ \beta_6 \log(BORDERS_{ij}) + \beta_7 \log(COMLANG_{ij}) \\ &+ \beta_8 \log(COLONY_i) + \beta_9 \log(COMCOL_{ij}) + \log(\eta_{ij}) \qquad (5) \end{aligned}$$

We considered the possibility of error term heteroskedasticity-induced estimation bias for the

[3] An anonymous reviewer suggested replacing the Internet use variable with an index measure. A helpful work of recent vintage is by Kauffman and Kumar (2008). They analyze three different aggregate country-level technology-related indices. These three measures were inappropriate for our empirical study due data unavailability for 2005 (the International Telecommunication Union's Digital Access Index) or too few countries represented in the index (the Economist Intelligence Unit's E-Readiness Index and the Center for International Development's Network Readiness Index).

model coefficients. This led us to conduct a visual analysis of the estimated model's error terms plotted against the outcome variable. We found that there was potential for unequal error term variances. This led us to apply the Breusch-Pagan and Cook-Weisberg tests for heteroskedasticity to determine if there were issues with the data that would introduce biased parameter estimates with opposite signs. The *p*-value was significant at the .01 level, suggesting that we should reject the null hypothesis of a constant variance for the estimated error term. This further suggested the appropriateness of weighted least squares (WLS) estimation. Our first approach was to find a weighing variable for known-source heteroskedasticity, but all combinations of variables and weighing options (absolute value of the residual, residual squared, log residual squared, fitted value squared) did not resolve the problem. We then used White's (1980) estimator to obtain an appropriate covariance weighting matrix to apply to the data. This approach was able to produce unbiased estimates.

6. RESULTS

We now discuss our base model's results, and what we learned from multiple stratifications.

6.1. Estimation Results for the Base Model

The base log-linear model is significant, as is each variable within it. Table 5 shows the estimated coefficients. The physical distance variables confirm previous studies. The negative coefficient for *DISTANCE* indicates that trade diminishes with distance. The positive coefficient for *BORDERS* signifies that bilateral trade is greater for countries that share a common border. The results for the cultural and political distance variables indicate that bilateral trade among countries which share a common official language (*COMLANG*), colonizer (*COMCOL*), or colonial relationship (*COLONY*) is higher than among countries that do not share these ties. Positioning these control variables to explain variance in bilateral trade flows permits us to analyze the true effects of the ICT variables on the outcome.

Table 5. Estimation Results for Base Log-Linear Regression Model

VARIABLE	COEFFICIENT	ROBUST STD. ERR.
HOME_GDP	0.999***	0.008
PTNR_GDP	0.936***	0.008
HOME_INET	0.077***	0.013
PTNR_INET	0.153***	0.011
DISTANCE	-1.099***	0.017
BORDERS	0.921***	0.091
COMLANG	0.732***	0.043
COLONY	0.722***	0.076
COMCOL	1.102***	0.065
Note: Model: Log-linear regression. N = 14,511. R^2 = .73, F-value = 4,457.75. Signif.: * = p < .1, ** = p < .05, *** = p < .01.		

Our results for the base model suggest that the ICT variables have significant effects on bilateral trade flows. In the home and partner countries, as Internet use increases (*HOME_INET*, *PTNR_INET*), bilateral trade flows also increase. This indicates support for the Overall Internet Use Hypothesis (H1).

6.2. Estimation Results for "Economic Size"

Next, we stratified our data based on economy size, so we could test our Economy Size Internet Use Hypothesis (H2). We separated the countries in the data set into GDP quintiles. We identified the bottom 40% of countries as "smaller economies" and the top 40% of countries as "larger economies." We dropped the data from the middle quintile. In this stratification, less-developed countries had GDP of less than $US36 billion while more-developed countries had GDP exceeding US$144 billion. (See the Appendix for the two top and two bottom quintiles.)

Our analysis involved three different sub-stratifications. They permit three different tests for: (1) home and partner economies that were both small, (2) home and partner economies that were small and large, and finally (3) home and partner economies that were both large. Based on our decision to drop the middle quintile of country development level data, the reader should recognize that all of the comparisons were within the lowest 40% quintile, across the lowest 40% and highest 40% quintiles, and within the highest 40% quintile of data. Table 6 shows the results of the country stratification estimations of bilateral trade flows.

The stratified model's results for the smaller home and partner economies in the 2nd and 3rd columns from the left in Table 6 explain the least amount of the variance in bilateral trade flows.

We used 2,477 of the original 14,511 observations, a solid size for estimation. We dropped the variable *COLONY*, since all the values were equal to 0. There were no instances of countries in the smaller quintile that had historical or current colonial ties with other countries in the stratification. The estimation results suggest that Internet use among smaller economies significantly contributes to higher trade flows. Interestingly, distance seems to play the greatest role in limiting trade between the smaller economies, but Internet technology seems useful level to overcome this distance limitation.

Table 6. Estimation Results by "Economic Size"

VARIABLE	SMALLER / SMALLER (e.g., Honduras and Bolivia) N=2,477		SMALLER / LARGER (e.g., Kenya and Germany) *N* = 5,823		LARGER / LARGER (e.g., Denmark and Canada) *N* = 1,260	
	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.
HOME_GDP	0.717***	0.038	0.997***	0.015	0.907***	0.027
PTNR_GDP	0.545***	0.033	0.937***	0.014	0.893***	0.027
HOME_INET	0.086***	0.284	-0.033*	0.018	0.018	0.036
PTNR_INET	0.181***	0.269	0.064***	0.016	-0.004	0.036
DISTANCE	-1.540***	0.451	-0.999***	0.028	-0.770***	0.030
BORDERS	1.130***	0.190	1.388***	0.154	0.406***	0.114
COMLANG	0.647***	0.099	0.628***	0.059	0.530***	0.096
COLONY	--	--	1.044***	0.094	0.002	0.148
COMCOL	0.827***	0.105	-0.939***	0.124	1.063***	0.105
	R^2 = .48, *F*-value = 374.9		R^2 = .59, *F*-value = 994.47		R^2 = .73, *F*-value = 377.21	

Note: Stratification: by GDP. Signif.: * = $p < .10$, ** = $p < .05$, *** = $p < .01$. The 4th and 5th columns from left only show results for bilateral trade flows when smaller economies are the home countries, and larger economies are the partner countries. This analysis is representative of our findings, since when we reversed the order to have larger economies as the home countries, the results yielded no new insights.

The second block of estimation results, in the 4th and 5th columns from the left in Table 6, show bilateral trade flows between smaller and larger economies, where one or the other is the home country. The results are more significant as a whole than for the smaller economies stratification, but less significant than for the larger economies stratification. All of the variables are significant at the $p < .01$ level, as was the case with the results for the entire data set, shown earlier in Table 5. This second stratification used a large sub-sample, with 5,823 of the original 14,511 observations. Internet use in the home country plays a greater role in bilateral trade than in the partner country, a reversal of the outcome we observed in the smaller economies stratification. Distance here also plays less of a role than in the smaller economies. Perhaps the increased wealth of the large economy requires more trading partners for their goods and services, and so there is a logical constraint on the production of a higher coefficient for Internet use.

The final stratification models trade among larger economies. This had a subsample size of 1,260 of the original 14,511 observations, but the highest model significance. Here, Internet use has no effect on bilateral trade flows among larger economies, and we see for the first time that colony relationship variable is also insignificant. This matched our expectations. Geographic distance plays the smallest role of any in this sub-sample among the three different stratifications. This suggests that the model has more explanatory power based on the economy size variables (GDP) than for the other sub-sample estimations.

The evidence that Internet use plays a significant role in trade among smaller economies and plays no significant role in trade among larger economies does not support the Country Development Level Internet Use Hypothesis (H2) as we have written it, although it makes sense to us after the fact of our analysis. One reason for a lack of significance in Internet use among larger economy country-pairs is the "information content" of the related variables. Most larger economies exhibit less variance in Internet use. While the larger economy country-pairs do have higher Internet use, the variance of that variable is actually higher in smaller economies, so there may be more capacity to capture the variance in the bilateral trade flows.

6.3. Estimation Results for "Country Distance"

To test the Distant Country-Pairs Internet Use Hypothesis (H3), we stratified the data for geographic distance between countries. We separated country-pairs into quintiles based on geographic distance. We identified the bottom 40% of country-pair distances as *less-distant countries* and the top 40% of country-pair distances as *more-distant countries*. We discarded the middle quintile. In this stratification, the less-distant country-pairs were closer than 5,223 kilometers apart while the more-distant pairs were farther than 7,910 kilometers apart. See Table 7 for the results.

The coefficient of determination, *F*, reveals that the model as a whole fits less-distant countries slightly better than more-distant countries. All variables are highly significant in both stratifications though. We dropped the *BORDERS* variable in the more-distant country pairs stratification, since all values were 0 and no bordering countries were more than 7,910 km apart.

Analyzing the relative size of the coefficients in each of the stratifications reveals some interesting findings. First, GDP is a stronger predictor of trade flows among more-distant countries. Second, distance is a stronger predictor of trade flows among less-distant countries. So in a cluster of less-distant countries like the European Union, the distance to trading partners matters more for predicting bilateral trade than for more-distant countries. If a country is going to trade with a more-distant country, then the difference between 8,000 and 10,000 kilometers is not a large deterrent. But, distance may be a greater deterrent to trade when the partners are less distant. The difference between 1,000 and 3,000 kilometers might be more of a deterrent than a difference of 8,000 and 10,000 kilometers, though the actual difference is identical. The marginal distance cost of trade decreases with distance. So the cost of doing business 1 kilometer farther away will be greater at 1,000 kilometers distance than at 8,000 kilometers. Finally, the effect of common language is stronger among less-distant countries, suggesting that countries are more willing to deal with language barriers with distant countries than close countries. Our data seem to suggest – rather interestingly, for example – that the Spanish-Portuguese language barrier between Chile and Brazil is a greater deterrent to bilateral trade than the Spanish-French language barrier between Chile and France.

Table 7. Estimation Results for Country Distance

VARIABLE	LESS-DISTANT COUNTRY-PAIRS (e.g., Panama and Bolivia) N = 5,809		MORE-DISTANT COUNTRY-PAIRS (e.g., Brazil and Thailand) N = 5,805	
	Coef.	**Std. Err.**	**Coef.**	**Std. Err.**
HOME_GDP	0.910***	0.013	1.098***	0.014
PTNR_GDP	0.873***	0.013	1.008***	0.011
HOME_INET	0.098***	0.031	0.097***	0.020
PTNR_INET	0.144***	0.029	0.169***	0.018
DISTANCE	-1.251***	0.035	-0.781***	0.095
BORDERS	0.787***	0.098	--	--
COMLANG	0.852***	0.060	0.322***	0.078
COLONY	0.928***	0.143	0.876***	0.182
COMCOL	1.102***	0.073	1.118***	0.111
	R^2 = .76, F-value = 2,005.99		R^2 = .72, F-value = 1,829.92	

Note: Model – "country distance" stratification. Signif.: ** = $p < .05$, *** = $p < .01$. Dashes for *BORDERS* indicate variable was dropped for the more-distant country-pairs analysis, since no bordering countries are more than 7,910 kilometers apart.

For the ICT variables, Internet use has a higher coefficient for more-distant than less-distant countries, supporting the Distant Country-Pairs Internet Use and Telecommunications Activities Hypotheses (H3). Internet use in more-distant countries is a stronger predictor of trade. This makes sense, since ICT allows for fast, inexpensive communication, regardless of distance. Less-distant countries are able to trade with each other with less ICT, while more-distant countries are hampered by distance and need to leverage ICT.

7. CONCLUSION

The effect of ICT on trade depends on the type of ICT use. Internet use, we found, is associated with greater trade, while traditional telecommunications are associated with less trade. A surprising finding was that ICT use has a greater impact on trade among smaller economies than among larger economies. The impact of ICT on bilateral trade flows also depends on the distance between the countries. More-distant trading partners experience more trade in the presence of ICT than less-distant countries.

Our proposed ICT-led trade cost reduction theory suggests that ICT reduces the costs of trading with distant countries. In the gravity model, countries with more ICT use will experience a stronger gravitational pull between them, increasing trade. This theory has implications outside of international trade, and is generalizable to other individual, firm, and industry contexts. Trading relationships, or other transactions that require communication within a country, an industry, or among individuals can benefit from increased ICT utilization.

We note a number of contributions of our work to the knowledge base for the area of global development and the impacts of ICT. First, we have identified the connection between the adoption and implementation of ICT and the flow of international trade between countries. Since international trade flows and ICT are known to provide complementarities to the economic performance of the countries that are involved, this research has identified a major role for ICT to help developing countries in their efforts to improve their economic and social welfare – a key aspect of the U.N.'s Millennium Development Goals.

Second, increasing levels of international trade also provide a basis for beneficial spillovers in the local economy of the home country that are highly beneficial to economic development. We expect them to involve knowledge transfer, process design capabilities sharing, and other relationship-based aspects that may lead to more effective utilization of resources in the home country, and better capacity to create, manufacture and deliver new products. These findings are in line with the research of Kauffman and Kumar (2008). They examined the extent to which different measures of development within a country can be tied to the adoption and implementation of ICT. When development outcomes are moderated by the distance between the country and the potential source of the impetus for development, there should be many other potential impacts of that will be of general interest.

Beyond these contributions, our findings also will inform policy-makers and managers, giving them additional confidence about the conclusions they can draw related to beneficial development considerations at the country level based on ICT's impacts on bilateral trade flows. While ICT investment does not necessarily lead to greater productivity in developing countries (Dewan and Kraemer 2000), there are trading benefits from ICT use and investments. ICT use will be even more beneficial to increasing trade with distant countries. This knowledge is useful for countries such as Australia, New Zealand, Argentina, Iceland and South Africa. These countries do not have the benefit of close geographic proximity to as many trading partners as, say countries within the European Union. They therefore can leverage IT to a greater extent with respect to influencing bilateral trade flows.

Some caveats for the reader are in order. ICT will never be able to fully mitigate the distance between trading partners. Cairncross (1997, p. 5) notes: the "death of distance loosens the grip of geography. It does not destroy it." ICT is a piece of the puzzle, indeed, more significant than was previously understood. But other variables in past research are worthwhile to explore. These include WTO affiliation, whether a country is an island or landlocked, whether two countries have common religion and population levels, and indices of remoteness, openness, and democratization. Including these will explain more variance in trade, but since none of these variables is likely to be highly correlated with Internet and telecom use, they would not alter our theoretical conclusions. We do not want to minimize the impacts that trade flows have on economies, and the related economic growth, and knowledge and productivity spillover effects. These are critical to a full understanding of trade flows and it would not matter if IT diminishes the negative impact of cultural and physical distance in international trade if the impacts were limited only to trade flows. Our goal is to understand the role of the influence of technology on the trade-limiting nature of distance, and this research has been helpful in making some inroads in that direction.

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Appendix. Larger and Smaller Economies by Continent and Region in the Data Set

CONTINENTS	COUNTRIES
• **Larger Economies**	
Africa	South Africa
America	
Central America	None
North America	Canada, Mexico, United States
South America	Argentina, Brazil, Venezuela
Asia-Pacific	
East Asia	China, Hong Kong SAR, Indonesia, Japan, South Korea, Thailand
Central Asia	Russian Federation
South Asia	India
Pacific Islands	Australia
Europe	
Eastern Europe	Poland, Turkey
Western Europe	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom
Middle East	Iran, Saudi Arabia
• **Smaller Economies**	
Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Swaziland, Sudan, Togo, Uganda, United Republic of Tanzania, Tunisia, Zambia, Zimbabwe
Americas	
Central America	Antigua and Barbuda, Barbados, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Haiti, Honduras, Jamaica, Panama, Saint Kitts and Nevis, Nicaragua, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago,
North America	None
South America	Belize, Bolivia, Guyana, Paraguay, Suriname, Uruguay
Asia	
Central Asia	Afghanistan, Armenia, Azerbaijan, Belarus, Georgia, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
East Asia	Brunei Darussalam, Macao Special Administrative Region, Mongolia,
South Asia	Sri Lanka, Nepal
Southeast Asia	Cambodia, Lao People's Democratic Republic
Pacific Islands	Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Palua, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga, Vanuatu
Europe	
Eastern Europe	Albania, Bosnia and Herzegovina, Bulgaria, Estonia, Latvia, Lithuania, Former Yugoslav Republic of Macedonia, Moldova, Montenegro, Serbia and Montenegro, Serbia, Slovenia
Western Europe	Iceland, Malta
Middle East	Bahrain, Jordan, Lebanon, Occupied Palestinian, Syrian Arab Republic, Yemen

Note: The *larger economies* represent the top two quintiles or 40% of the countries in our data set, using a GDP-based stratification of the data. The *smaller economies* represent the bottom two quintiles or 40% of the countries in our data set.