Overcoming the Adverse Effects of Geography: A Cross-Country Analysis of Information and Communication Technology (ICT) Diffusion on Economic Development

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Abstract

In the sweeping speed of digital revolution, changes of the landscape of technology may profoundly alter the very nature of place and physical factors, such as access to raw materials and ports. The question of "Does place still matter?" remains unsolved. Thus, using panel data for 75 middle- income countries for the period 1996 to 2008, the paper addresses the question: *Does ICT diffusion overcome geographic disadvantages in economic growth?* It finds that ICT diffusion does show positive correlations in economic growth for inland and geographic remote countries. These findings may help policy-makers to formulate new spatial-economic policies and ICT investment strategies that may accelerate economic development.

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I. INTRODUCTION

We are in the era of digital revolution, which has not been seen since the onset of the industrial revolution. Such changes may "profoundly alter the very nature of places and its importance by deemphasizing physical factors – such as access to raw materials and ports". (Kotkin, 2000, p.5) These new spatial landscape may be shaped by new forms of information and communication technology (ICT) which is fundamentally different from geographical nature. However, *does ICT Diffusion overcome geographic disadvantages in economic growth?*

With the unprecedented degree of ICT diffusion, the global economy has witnessed increasing market integration but unbalanced spatial economic growth. Unequal economic development and geographical clustering of high growth nations and industries have many explanations. Studies of the effects of geography on economic growth can be traced back to Adam Smith (1776) who while stressing the importance of the economic institutions, also emphasized the geographic correlates of growth. Another reason proposed more recently by Noble Laureate Paul Krugman (1991) is the "new economic geography theory". Krugman stressed that not only "first-nature geography", which he defines as "the physical geography of climate, topology and resource endowments", but also "second-nature geography" defined as "the location of economic agents relative to one another in space" explains the distribution of economic activity. Other researchers (Redding, 2009; and Leamer and Storper, 2001) now suggest that, with the diffusion of communication technology, a new "information geography" may emerge which could tremendously lower transport costs and that proximity to the global market may no longer be as important.

This paper examines the role of ICT diffusion in explaining cross-country differences in economic development controlling for geographic characteristics, as well as other institutional, political, and economic factors. Using panel data for 75 middle-income countries for the period 1996–2008, the paper addresses the question:

Does ICT Diffusion overcome geographic disadvantages in economic growth?

By answering the question, the paper aims at helping policy-makers from geographical disadvantage countries to better formulate economic policies and ICT investment strategies that may affect their countries' economic development.

I. LITERATURE REVIEW: GEOGRAPHY, TECHNOLOGY AND ECONOMIC DEVELOPMENT — THEORETICAL LINKS

Geography and Economic Growth

As noted above, studies of the effects of geography on economy growth can be traced back to Adam Smith (1776). More recently, historians such as Jared Diamond (1997) have suggested that geography is at the center of the explanation of economic growth. In addition, a large economics literature, including Easterly and Levine (2002) and Rodrick *et al.* (2002), has recognized three main sources of economic growth: geography, institutions, and trade policy (market integration), with culture and religion as two other possible sources. McArthur and Sachs (2001) also suggest that "both institutions and geographically-related variables" play a role as economic growth determinants.

Curiously, however, researchers such as Acemoglu *et al*., (2001) have raised doubts about whether geographical conditions have an effect on institutions and suggested that geographic conditions could be seen as only a proxy for the quality of institutions. Nonetheless, it seems indisputable that geographic fundamentals affect the climatic and public health conditions of a country, as well as the transport costs of access to markets, especially international markets. A recent report from the World Bank -- *World Development Report (2009): reshaping economic geography* -- argues that three main intersectional geographic factors, namely, density, distance and division together with three driving forces, agglomeration, migration, and specialisation in international trade are at the center of the economic development across countries. This report puts the spatial dimensions of economic development at center stage in the policy realm.

According to Gallup, Sachs and Mellinger (1999), empirical findings about the effects of geography on economic growth are: (1) Tropic areas are slower than temperate regions in economic development, probably because of higher disease burdens and limitations on agricultural productivity. (2) "Coastal regions, and regions linked to coasts by ocean-navigable waterways, are strongly favored in development in relative to the hinterlands". (3) Landlocked countries may have particular disadvantages in development even when they are close to the interior parts of their coastal neighbors. (4) High population density seems to have a positive effect on economic development for the coastal economies, but not for the hinterland where high population density seems to be a net disadvantage. And (5) Human population growth tends to be strongest at the countries which are least equipped to achieve rapid economic growth; thus population growth across countries recently shows strong negative correlation with these countries' relative potential for economic growth.

Noble Laureate Paul Krugman (1991) has developed a somewhat different theory — "new economic geography" or "new growth" theory — to explain the uneven distribution of economic activity across space, and the modern clustering of development in small geographical area in our modern economy. He proposed that two forces: (1) agglomeration forces which arise from positive externalities (e.g. spillovers) due to a combination of love of variety preferences from a increasing returns to scale and a reduction on transport costs; and (2) "the dispersion forces [a]risen from product market competition and geographically immobile factors of production or amenities which depend on transportation costs", determine the location choices. These forces of agglomeration and dispersion imply that, according to Venebles (2009), "spatial unevenness in economic activity and incomes is an equilibrium outcome".

Following his theory, economists such as Venebles (2009), Hummels (2001) and Anderson and van Wincoop (2004) suggest that geographic distance still matters even for modern trade and an integrated global economy. They conclude that knowledge spillovers still cluster in very concentrated economic regions. Labor market effects and institutional effects are also influenced by distance because geographic distance "raises the monetary and time cost of trading goods, moving workers, or spreading ideas". Moreover, "underlying jurisdictions and hence man-made barriers to mobility" also increases the difficulties. (Venebles, 2009)

Some researchers (e.g. Barro and Sala-i-Martin, 1995) argue that, with the march of globalization, regional economies may be converging. However, the impact of geography on the rate of convergence and on the initial stage of economic development is still prominent in the economic development literature.

ICT Diffusion and Economic Growth

A positive correlation between ICT diffusion and economic growth has been established by researchers such as Jukka and Pohjola (2002) and Oliner and Sichel (2000). Other researchers, such as Roller and Waverman (2001) and Gruber and Koutroumpis (2011), show that elements of ICT diffusion like telecommunication infrastructure, mobile phone usage, internet access and broadband development have a positive impact on economic growth, though most of these researches focus on developed countries. Torero and Braun (2006) also convincingly suggest a causal effect of ICT diffusion on economic growth**.**

Researchers such as Oyelaran-Oyeyinka and Lal(2003), Baliamoune-Lutz (2003) and Hargittai (1999), however, suggest that digital diffusion widens the technology gaps between developed and developing countries and that industrial countries seem to benefit from the technology diffusion at a faster pace and a wider spectrum on economic activities than less developed countries. Other researchers who are less negative suggest that developing countries may enjoy the benefits of technology diffusion after they pass some threshold (e.g. a 5% - 15% penetration rate) (Torero and Braun, 2006, p338.). These developing countries may also “leapfrog” the traditional technology diffusion stage and benefits from the most up-dated technology (Torero and Braun, 2006).

Geography, Technology Development and Economic Growth

As noted above, Bosker and Garretsen (2010), and Anderson and van Wincoop (2004) suggest that technology diffusion reduces transport costs. But Hummels (1999), Leamer and Storper (2001) and Rose (1999) raise doubts about the reduction in "communication costs at long distance" and suggest that reducing the cost of shipping goods might not necessarily reduce the effect of geographic distance, since the portion of transportation and communication costs to total production costs is very small. However, they do not provide convincing empirical evidences to support these views. Moreover, the effects of communication and transportation on the business and economies as a whole should not be evaluated solely based on their costs, but rather be examined as a whole synergy (a positive externality such as knowledge spill-over) effect to the economy.

Inevitably, economic growth tends to be "lumpy" (Venebles, 2009) with some sectors in some regions growing faster than other regions. Activities such as face-to-face communication, body language and mutual trust building which are crucial in business relationships and trade partnerships can hardly be transferred by using email, phone or even video conferencing. And long term deep relationships can hardly be established without complex and multidimensional communication (Leamer and Storper, 2001). This may be the reasons why commerce begins from neighborhoods. However, according to Leamer and Storper (2001), business activities of producing large scale, standardized and codified goods and services may be one of the better ways for countries to overcome their geographic disadvantages.

In sum, the theoretical case for the effect of technology diffusion on economic development of geographically disadvantaged countries is far from unequivocal. Rather, the analysis and evidence reviewed above suggests that technology diffusion[a] has ambiguous effects in relation to economic growth for geographic disadvantaged countries. Thus, the paper aims to combine the two important blocks of the economic development theories and to test the hypothesis whether ICT diffusion might be able to help overcome geographic disadvantage.

Intuitively, countries that suffer from exogenous factors – “first nature geography” and “second nature geography” disadvantages – may need to seek for spatial policies that aim at changing the relationship between regions, such as trade policy, road and ICT infrastructure improvements. (Venebles, 2009)

II. Conceptual Framework

As discussed above, theories of geographic determinants of economic growth and theories of the effects of ICT diffusion on economic growth are well established. Theory of geographic determinants on economic development suggests a causal relationship of health and environment, institution, integration and trade and geography on economic growth. However, theory of the effects of ICT diffusion on economic growth suggests a different hypothesis about the relationship of institution, integration and trade and ICT diffusion on economic development i.e. that ICT diffusion has a positive effect on economic growth.

[a] Though there are many aspects of technology, this paper focuses on information communication and technology (ICT).

This paper empirically tests the hypotheses about the potential effects of ICT diffusion on economic development for these geographically disadvantaged countries:

H_0: ICT diffusion has no effects on economic development for countries that are geographically disadvantaged.

H_1: ICT diffusion has a positive effect on economic development for countries that are geographically disadvantaged.

III. METHODOLOGY AND DATA

The Base Model

This paper will start with a baseline economic growth model similar to Barro and Sala-i-Martin (1995) who defined average annual economic growth is a function of initial income; education attainment; openness of economy to international trade; health and environment indicators, and the quality of public administration. However, the paper also considers technology diffusion Gompertiz model: Baliamoune-Lutz (2003) and Gholami, Lee and Heshmati (2003) which assumes that per capita income, economic policy variables, openness of trade and political freedom indicators are the main determinants of the equilibrium level of ICT development. The paper also builds on Shamin (2007), who suggests an economic growth model that takes ICT development and financial depth into account. Based on these previous models, the present study estimates economic growth as a function of Informational and Communication Technology (ICT) indicators and other necessary controls in the equation:

$$Growth_{it} = \beta_0 + \beta_1\, GDPp.c._{i1996} + \beta_2 Geography_i + \beta_3 Education_{it}$$

$$+\beta_4 Trade\ Openness_{it} + \beta_5 ICT_{it} + \beta_6 Insititution_{it} + \beta_7 Health_{it}$$

$$+\beta_8 Geograp_i \times ICT_{it} + \beta_9 Other_{it} + \varepsilon$$

where $Growth_{it}$ is the annual growth rate of the country *i* in the year *t*, and ε is the error term; ICT variables include three key variables of interest, namely, cellular mobile subscribers per 100 people, internet users per 100 people, and telephone lines per 100 people[b]; geography indicators are using population density within 100 kilo meters of coastline as a measure for landlocked (when population density at the coastal area is zero) or remote countries, and percentage of land in tropic areas; health and environment variables include the malaria index, and life expectancy data; trade openness variables include openness index from Penn World; education variables are enrollment for secondary schools; institutional variables are political stability, civil liberty and political right indicators. Following the example of previous research, the paper also takes account of the likely endogeneity of the explanatory variables by using lagged values as instruments.

But the ICT effects for countries that are landlocked may be influenced by neighboring countries' political proximity, neighbor countries infrastructure, neighbor countries' peace and stability and neighbor countries administrative practices (Faye, McArthur, Sachs, and Snow, 2004), since they need to rely on neighbor countries' access to international shipments. Therefore, it is difficult to see the isolated effect based on our model for the landlocked or remote countries.

Furthermore, countries that suffer severe political, economic and social problems may need time to benefit from the development of ICT infrastructure. For example, in Western Africa which is suffering from internal strife, surrounding civil wars, tense

[b] The paper also uses an aggregated ICT index of the three variables.

regional relations, poor transport infrastructure, unstable political institutions, and harsh rain seasons, the effect of ICT on trade may be less obvious in the near future. Similarly, former Soviet Union countries face severe inter-regional transport problems, poor diversification of exports, remoteness and dispersion of urban areas, and regional tension, may also observe limit effects of ICT development. It is probable that the effect of ICT infrastructure development has a time lagged effect on economic development. Communication can only impose a certain amount of enforcements. Communication at a distance may need more time to build trust in business relationship than when communication is face-to-face. Business norms and international standard practices may also take more time to adopt through virtual than through direct communications.

The Data

Dependent Variable

The dependent variable is GDP per capita growth (annual %) obtained from the World Bank's World Development Indicator from 1996 to 2008 on 98 middle-income countries[c] due to limitation of political indicators. The growth rate has been normalized as 3-year moving average to smooth the effect for external shocks. However, Models 2 to 5 use only a subset of the sample (75 middle-income countries)[d] due to limitation of the geography indicators.

Independent Variables

Key independent variables of interest

[c] List of countries are shown in Appendix.
[d] List of countries are shown in Appendix.

The set of ICT indicators for 1996-2008 in 98 (full sample) or 75 middle-income countries (subsample) are taken from the World Bank and International Telecommunication Union. There are four main ICT indicators: cellular mobile subscribers per 100 people, internet users per 100 people, telephone lines per 100 people, and number of Internet Servers per 100 inhabitants. I eliminate the last indicator due to problems of missing data. But the three remaining indicators should adequately capture the state of the ICT infrastructure. The correlation between internet users and mobile users is .80. But telephone users' variable does not show a strong correlation between the other two variables, with Pearson correlation of .54 and .45, respectively. Therefore, the paper also uses an aggregated ICT index of the three variables. Although some previous researchers use only one of these indicators, others argue that a single indicator may not necessarily provide a full picture of the ICT infrastructure level of a country. Additionally, for most developing countries, the number of cellular mobile subscribers per 100 people, internet users per 100 people, and telephone lines per 100 people are in fact very different. There may also be heteroskedacity problems with these variables, since the more recent the year the higher level of ICT development potentially and the higher the level of economic development. This problem is shown in Figures 2-4 in the Appendix. Thus, I have used robust tests to minimize the effect of heteroskedacity.

Geographic indicators

The geographic data are obtained from the University of Essex and the Center for International Development at Harvard University on 75 middle-income countries. The data is last updated in 2001. The population density within 100km of coastline is measured as percentage of overall population. It is used as a measure for landlocked (when population density at the coastal area is zero) or remote countries. Percentage of land in tropic areas is measured as a percentage of land in the tropic area. This variable is believed to be correlated with the health and environment variables such as the malaria index.

Other control variables

My data for per capita income is obtained from the Penn World Table for 97 (full sample) or 75 (subsample) countries from 1996 to 2008 with PPP adjusted at the international price. This variable is predicted to be negatively correlated with higher economic growth rates. It is also used as a lagged variable in the year of 1996 in order to capture the initial economic stages. According to Barro and Sala-i-Martin (1995), this instrument procedure "lessens the tendency to overestimate the convergence rate" due to measurement error in GDP.

Indicators of level of education[e] across countries come from World Bank WDI dataset. Although previous research shows that tertiary education is important for internet usage diffusion, the paper does not include this indicator due to problem of missing data. Moreover, the paper only includes quantitative measure of education indicators (number of students' enrollment) mainly because of the limited data for the qualitative measure of the education such as tests scores.

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[e] Barro and Sala-i-Martin (1995) suggests using the lagged variable for enrollment in order to control the initial stages. I have tried using lagged enrollment of secondary school, but with similar result. Result is not reported.

Openness to trade indicator includes the openness index in 2005 from Penn World. It is measured as Export plus Import divided by total GDP at national currencies at real values.

Indicators of institutions including political freedom and rule of law are Freedom House's Index and World Governor's Indicator from the World Bank. Previous researches on similar studies do not find these indicators conclusive in explaining economic growth.

Public health indicators include life expectancy and the malaria index from World Bank WDI and Center for International Development (CID). Data for life expectancy and malaria index are taken as lagged variables for the year of 1994 to capture the initial stages of the health conditions.

Additional control variables such as hydrocarbons per capita (used in log form) and region dummies are taken from Center for International Earth Science Information Network (CIESIN), Columbia University and Centro Internacional de Agricultura Tropical (CIAT) 2005.

Missing Data

In Model 1(full sample), missing data in all variables are less than 5%, except for data from Freedom House which has missing data of 8.85%. In Models 2 to 5 (subsample), missing data in all variables are also less than 5%, except for education enrollment data which has 15% missing data. Tests show that there is no statistical significant evidence that missing data are biasing the results (i.e. missing data seems to be random in either case.).

Table 1 shows a summary for the descriptive statistics of the data.

Table 1- Descriptive Statistics

		N (Full/ Subsample)	Num of Countries (Full/ Subsample)	Mean	S.D	Min	Max	Source
	Growth rate	1256/995	98/75	3.24	3.96	-17.24	35.04	World Bank
Initial per capita income	Log GDP per capita	1249/995	97/75	8.25	.71	6.76	9.71	Penn World
Education	Enrollment (Secondary)	-/743	-/76	70.23	23.58	12.02	114.08	World Bank
Institutions	Civil liberty	1256/943	98/73	3.63	1.65	1	7	Freedom House
	Political freedom	1254/942	98/73	3.63	2.08	1	7	Freedom House
Openness of trade	Openness	1249/995	-/77	88.27	37.94	14.27	260.43	Penn World Table
Geography	% Of land in tropic area	-/995	-/75	.51	.47	0	1	CID
	Population density within 100km coast line	-/995	-/75	.41	.35	0	1	CID
ICT indicators	Mobile users per 100 inhabitants	1240/994	97/77	22.70	30.58	0	157.22	World Bank, ITU
	Telephone users per 100 inhabitants	1243/995	97/77	12.63	10.75	.21	57.53	World Bank, ITU
	Internet users per 100 inhabitants	1215/982	97/77	7.68	11.04	0	74.82	World Bank, ITU
Other controls	Life expectancy 1996	-/995	-/77	65.65	7.23	42.50	77.02	World Bank
	Malaria index 1994	-/995	-/75	.23	.36	0	1	CID

Estimation methods

The paper uses a series of estimation models. Model 1 uses a sample of 97 middle-income countries; whereas Model 2 to 4 use a subset of the sample with 75 middle-income countries due to the limitation of geography indicators. The paper only reports pooled OLS estimation to see the average effects of economic growth with different sets of explanatory variables. Random effect estimate and fixed effect have also been used to test the robustness of the model.

Based on the assumptions of the OLS model, I have conducted tests on outliers, normality of residuals, homoscedasticity, multicollinearity, linearity, and issues of independently and identically distributed (i.i.d) random effect. Ramsey RESET tests show that there is no apparent non-linearity in the regression equations. There also does not seem to have autocorrection problem after I control for the lagged variables. However, problems of homoscedasticity and functional forms of some variables may still exist.

V. RESULTS

The analysis begins with three models to examine the effect of ICT diffusion on economic growth for geography disadvantage countries, as shown in Table2.

Similar to Shamin (2007)'s results using a similar model, Model 1with the full sample of 97 countries shows that two of the ICT indicators are highly statistically significant and of the positive sign. Internet usage, which is not significant at conventional levels, is also expected, since the usage of Internet in our sample countries are highly affected by the diffusion of telephone lines or/and mobile phones. F test of these three variables shows a jointly significant different from zero at 1% level. And F test of the three variables shows that the three variables are statistically different from each other. After aggregating the three ICT variables, the overall effect of ICT Index on economic growth is positive at 1% level[f]. Thus, estimates of Model 1 seem to be

[f] Results are not shown.

generally consistent with previous studies that ICT diffusion is positively correlated with economic growth.

Additionally, consistent with the finding of Barro and Sala-i-Martin (1995), Sachs (2005) and Faye, McArthur, Sachs and Snow (2004)'s, Model 2 indicates that landlocked (population density within 100 kilometers of coast line = 0) and tropic countries are disadvantaged for economic growth. Compared to landlocked countries (population density within 100 kilometers of coast line = 0), countries that are closer to the coastline may have a positive geography benefits in economic growth. However, unlike previous researches, it is surprising that the coefficient is not statistically significant. This could be resulted from the data is much newer than those used by previous researchers, since ICT infrastructure, by the time of 1996, have been in place and the economic effects of geography remoteness may have been reduced. Indicators of tropic area and malaria are highly significant and of expected signs. Political stability, in this model, also seems to show a significant contribution to the economic growth.

In Model 3, both geography and ICT indicators are included. To capture the conditional effect of ICT on geography remote countries, interaction terms are also included. The main effect of geographic remoteness measured by population density within 100 kilometers of coast line becomes statistically significant at 10% level. And the joint effect of geographic remoteness is also significant at 10% level (P value = .07). This is consistent with the previous model that countries that are closer to the coast lines seem to enjoy 1.296 units[g] more on growth rate than landlocked countries (population density within 100 kilometers of coast line = 0) on average, controlling for initial economy,

[g] Assume mobile phone usage is zero.

political, education, openness, ICT and health and environmental factors. Additionally, two of the three ICT indicators are significantly correlated with economic growth in a positive direction. Specifically, the effect of mobile phone usage on economic growth is highly significant and of positive sign, both on the main effect and joint effect (F statistic significant at 1% level). Similarly, telephone line usage also has a significant and positive effect on economic growth both in terms of main effect and joint effect (F statistic significant at 5% level). Internet usage seems to have a positive effect on economic growth but the result is not statistically significant at conventional levels. Furthermore, it is statistically significant that mobile phone usage have a negative effect on economic growth on condition to geography remoteness of the countries. Compared to the effect on countries that have medium population density at the coastal area in the sample[h], it is statistically significant that the effect of mobile phone diffusion on condition to inland countries is 0.4256 units[i] smaller on economic growth than to coastal countries. Compared to countries that have all population at the coastal area, landlocked countries enjoy 1.25 units smaller economic growth rate under the effect of mobile phone diffusion, holding other variables constant. In other words, the denser the countries at the coastal area, the less benefits these countries enjoy with mobile phone diffusion. Intuitively, countries that have a population more spread out to the inner land area may enjoy the benefits of mobile phone diffusion on economic growth more. This would be understandable since domestic communication and market integration via ICT

[h] Medium population density at the coastal area in the sample is 0.34.
[i] For $y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 (x_1 \times x_2) + \varepsilon$, the effect on Y of a change in X1, holding X2 constant, is $\frac{\Delta y}{\Delta x_1} = \beta_1 + \beta_3 x_2$, which depends on X2. (Stock and Watson, 2012).

development are also of crucial value to economic growth. The result shows that landlocked countries tend to benefit more on economic growth from mobile phone diffusion than coastal countries.

This conditional effect of ICT usage on economic growth on geography remote countries is shown more clearly in Model 4 when an aggregated ICT index is used. Countries that are closer to coastlines are statistics significant correlated with 1.542 units[j] increase in economic growth, compared to countries that are landlocked on average. But the effect of ICT diffusion on economic growth on condition to inland countries is 0.48 units less in the magnitude than to countries with a medium population density level at the coastal area at 5% significant level, holding other variables in the model constant. Similarly, the effect of ICT diffusion on economic growth on condition to landlocked countries is 1.425 units less than that to countries with all population concentrated at the coastal area at 5% significant level, holding other variables constant. It is statistically significant that landlocked countries benefit more from the effect of ICT diffusion on economic growth than coastal countries.

Across specifications, the effects on economic growth of initial economy stage, education, political stability and ICT indicators in countries seem to be robust. However, countries having a significant proportion of national territory in a tropical region appear to have a negative effect on economic growth. Malaria may also plague countries' economic growth. Initial life expectancy, surprisingly, shows a statistically significant negative correlation with economic growth. This could be explained by the short time span of the data in the sample. Life expectancy of countries can hardly change much

[j] Assume mobile phone usage is zero.

within a decade; however, economic growth rate may vary a great deal. For example, Iraq in the sample has life expectancy of over 70 from 1996 to 2008, but she experienced tremendous economic downturn some times in the past decade with an economic growth rate of about negative 40%. The models do not include variables such as war indicators, and this variable may suffered from omitted variable bias. Thus, the negative sign of the coefficient of life expectancy may not necessarily reflect the true story of the causality in economic growth in this regard. Rather generally, ICT development may have a bigger effect on economic growth for geography remote countries, with control for institutions, openness of trade, economic conditions, and education[k].

[k] To control for autocorrelation, I use several lagged variables.

Table 2 . Estimates from Regressions of Annual Economic Growth Rate 1996-2008

		Full sample	Sub-sample		
		Model 1[i]	Model 2	Model 3	Model 4
Economics	Ln (GDP p.c.1996)	-1.897***	-1.500***	-2.484***	-2.287***
		(.2300)	(.3713)	(.4014)	(.3681)
Openness of	Openness index	.0042	.0134	.0044	.0046
Trade		(.0046)	(.0087)	(.0088)	(.0086)
Education	Ln(enrollment	-	.0638***	.0398**	0.388**
	(secondary)		(.0156)	(.0126)	(.0130)
Institutions	Civil liberty	.6138**	.1391	.6204*	-.1594
		(.1954)	(.3511)	(.3765)	(.3626)
	Political right	-.1101	.1342	-.1745	.2990
		(.1575)	(.5540)	(.3346)	(.2772)
	Political stability		.6568**	.7657*	.8470**
			(.3221)	(.2791)	(.2780)
Geography	Population density	-	.1342	1.296*	1.542**
Indicators	w/in 100km coastline		(.5540)	(.7462)	(.7603)
	%Land in tropics	-	-1.634**	-1.116**	-1.120**
			(.5136)	(.5666)	(.4953)
Health &	Malaria index 1994	-	-1.920*	-.2519**	-2.584**
Environment			(1.132)	(1.120)	(1.142)
	Life expectancy 1996	-	-.1849**	-.1924***	-.1900***
			(.0591)	(.0577)	(.0579)
ICT	Telephone lines	.3906***	-	.3373**	-
		(.0931)		(.1244)	
	Mobile users	.0576***	-	.0115***	-
		(.0165)		(.0222)	
	Internet users	.0321	-	.0492	-
		(.0383)		(.0670)	
	ICT Index	-			.1420***
					(.0361)
Interaction	Teleline X pop100km	-	-	-.0072	-
				(.0543)	
	Mobile X pop100km	-	-	-.0441**	-
				(.0168)	
	Internet X pop100km	-	-	.0536	-
				(.0533)	
	ICT X pop100km	-	-	-	-.1171**
					(.0571)
	Lagged ICT variables	Yes	-	Yes	Yes
	R-squared	.1970	.2515	.3541	.3495
	N	933	463	460	446

* =0.1 alpha level **=0.05 alpha level ***= 0.01 alpha level   Robust standard error in parenthesis

[i] Random effect and fixed effect models with aggregated ICT index gives robust significant results. However, only pooled OLS estimates are reported here for the ease of interpretation.

VI. Robustness

After controlling for region dummies, log of hydrocarbons per capita 1993 and other political and institutional indicators such as government effectiveness, and voice and accountability, the results still hold. However, after using random effect in Model 3 and Model 4, the interaction terms are no longer significant. There would be reasons to believe that the effect of ICT development of economic growth for geography remote countries may not be shown in such a short time. Additionally, virtual communication of ICT may not be enough for crucial complex communication which builds trust and long-term relationship in international business. Admittedly, even though all of the model controls for several lagged values as instruments, there may still be endogeneity and identification problem. Subsequent studies should use more sophisticated estimation methods such as instrument variables (IV) or GMM estimates to test for these effects.

V. Implication for Policy and Further Research

The paper seeks to shed light on whether inland or remote countries can overcome their geographic barriers via ICT development, since development may increase communication across regions and reduce transport costs - one of the most important factors in international trade and economic development. Overall, the findings support the hypothesis that ICT infrastructure does help overcome countries' geographic remoteness on economic development.

The findings have important policy implications. It has been suggested that countries which are inland or remote from access to global markets are less competitive in international trade because of relatively high transport costs, and therefore these countries have remained among the poorer states. (Faye, McArthur, Sachs, and Snow, 2004; Grigoriou 2007) According to *Human Development Report 2011*, thirteen landlocked countries are classified as "low human development" states and none of the non-European landlocked countries is classified as "high human development". However, this study suggests that by developing ICT infrastructure, these geographically disadvantaged countries may be able to benefit more fully from international trade market. Countries that are landlocked or have less area close to coastlines should focus intensively on ICT infrastructure so as to reduce to adverse impact such as high transport costs or communication difficulties. Moreover, the fewer land territory with easy access to coastlines that countries have, the more important it is for them to develop domestic ICT infrastructure. Furthermore, Leamer and Storper (2001) suggest that less developed countries with lower prosperity in geography, albeit through the leverage of such spatial policy, may need to focus on "high-scale, standardization, routinization and codification of underlying knowledge and information" products and services which generally permit long distance transactions to be carried out.

The findings of the paper suggest that geographically remote countries face different sets of economic development challenges, so they should adopt different strategies on ICT infrastructure development, transportation costs reduction, and global market integration for economic development. However, this paper does not investigate the specific obstacles faced by specific landlocked or remote countries. Further research on the market structure of the individual countries and political and economic impact of neighbor countries may be necessary. The paper also does not answer the questions of how to reduce transport costs through ICT development to enhance economic integration, or how much ICT infrastructure investment affect the transport costs for specific geographically remote countries. Further research on such topics is encouraged and necessary.

Overall, the paper suggests that, with the advancement ICT that may leap-frog developing countries to the frontiers of global interaction, geography remoteness may no longer be as predominated to economic development as before. In an era of digital revolution, new spatial economy landscape may emerge overtime.

APPENDIX

Table Appendix - 1. List of countries (full sample)

1	Angola	34	Grenada	68	Pakistan
2	Albania	35	Guatemala	69	Panama
3	Argentina	36	Guyana	70	Peru
4	Armenia	37	Honduras	71	Philippines
5	Antigua & Barbuda	38	Indonesia	72	Palau
6	Azerbaijan	39	India	73	Papua New Guinea
7	Bulgaria	40	Iran,	74	Paraguay
8	Bosnia & Herzegovina	41	Iraq	75	Russian Federation
9	Belarus	42	Jamaica	76	Sudan
10	Belize	43	Jordan	77	Senegal
11	Bolivia	44	Kazakhstan	78	Solomon Islands
12	Brazil	45	Kiribati	79	El Salvador
13	Bhutan	46	St. Kitts & Nevis	80	Sao Tome & Principe
14	Botswana	47	Lao	81	Suriname
15	Chile	48	Lebanon	82	Swaziland
16	China	49	Libya	83	Seychelles
17	Cote d'Ivoire	50	St. Lucia	84	Syrian Arab Republic
18	Cameroon	51	Sri Lanka	85	Thailand
19	Colombia	52	Lesotho	86	Turkmenistan
20	Cape Verde	53	Lithuania	87	Tonga
21	Costa Rica	54	Latvia	88	Tunisia
22	Cuba	55	Morocco	89	Ukraine
23	Djibouti	56	Moldova	90	Uruguay
24	Dominica	57	Maldives	91	Uzbekistan
25	Dominican	58	Mexico	92	St. Vincent & the Grenadines
26	Algeria	59	Marshall Islands	93	Venezuela
27	Ecuador	60	Macedonia,	94	Vietnam
28	Egypt,	61	Mongolia	95	Vanuatu
29	Fiji	62	Mauritania	96	Yemen
30	Micronesia,	63	Mauritius	97	Zambia
31	Gabon	64	Malaysia		
32	Georgia	65	Namibia		
33	Ghana	66	Nigeria		
		67	Nicaragua		

Table Appendix -2. List of countries (sub-sample)

1	Angola
2	Albania
3	Argentina
4	Armenia
5	Azerbaijan
6	Bulgaria
7	Bosnia & Herzegovina
8	Belarus
9	Bolivia
10	Brazil
11	Botswana
12	Chile
13	China
14	Cote d'Ivoire
15	Cameroon
16	Congo,
17	Colombia
18	Costa
19	Cuba
20	Dominican
21	Algeria
22	Ecuador
23	Egypt
24	Gabon
25	Georgia
26	Ghana
27	Guatemala
28	Honduras
29	Indonesia
30	India
31	Iran
32	Jamaica
33	Jordan
34	Kazakhstan
35	Lao
36	Lebanon
37	Sri Lanka
38	Lesotho
39	Lithuania
40	Latvia
41	Morocco
42	Moldova
43	Mexico
44	Macedonia,
45	Mongolia
46	Mauritania
47	Mauritius
48	Malaysia
49	Namibia
50	Nigeria
51	Nicaragua
52	Pakistan
53	Panama
54	Peru
55	Philippines
56	Papua New Guinea
57	Paraguay
58	Romania
59	Russian
60	Sudan
61	Senegal
62	El Salvador
63	Syrian Arab Republic
64	Thailand
65	Turkmenistan
66	Tunisia
67	Turkey
68	Ukraine
69	Uruguay
70	Uzbekistan
71	Venezuela,
72	Vietnam
73	Yemen,
74	South Africa
75	Zambia

Figure 1. Growth rate versus Mobile user (partial relation)

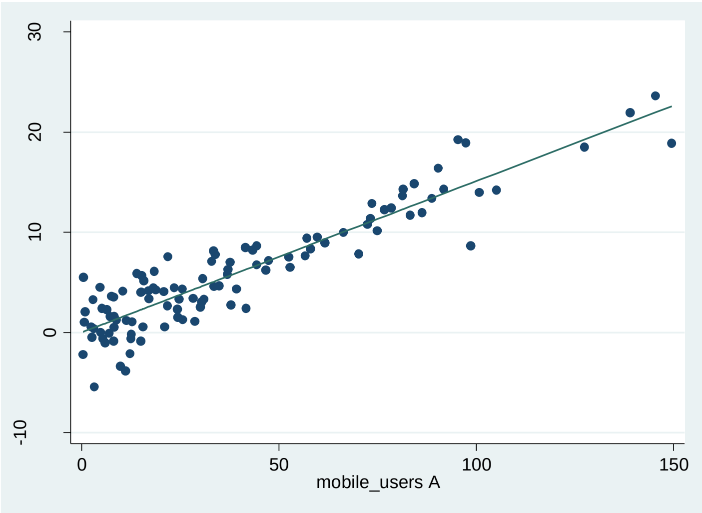


Figure 2. Growth rate versus telephone line users (partial relationship)

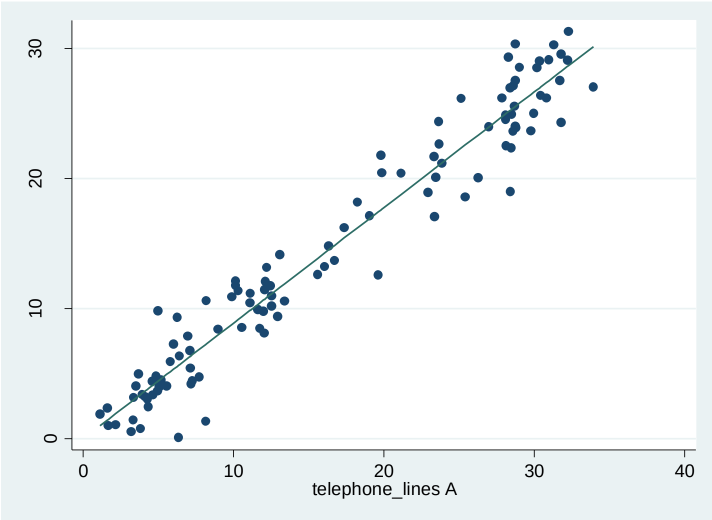
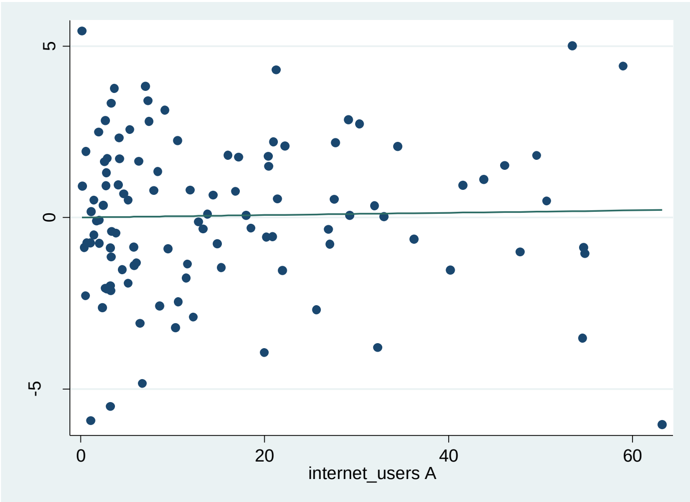


Figure 3. Growth rate versus internet users (partial relationship)



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