Plan B Paper

Decomposition of Information and Communication Technology for Development: A Case for Investment in and Trade of Intellectual Property

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Outline

Abstract

This paper examines developing countries' ability to increase output capacity in order to become competitive in international trade while fostering market diversification by investing in a portfolio of industries instead of specializing in one industry. Measuring the impact that information and communication technology (ICT) has on competitiveness in the export market, I examine the applied research question: does investment in ICT infrastructure stimulate export trade in intellectual property, specifically, in the area of copyright related goods and services? The motivation for this research is twofold: 1) the growing digital divide between developed and developing countries needs to be addressed for development and prosperity; and 2) the growing number of industries impacted by ICT (as measured by the number of industries that have sales related to ICT) meets the goal of diversifying developing economies. If I find that returns to ICT are the same in both developed and developing countries and the gap in ICT related trade is due to endowments of ICT, this supports the Heckscher-Olin model's theoretical predictions on patterns of trade. However, if I find that returns to ICT are different between developed and developing countries and that the ICT related gap in trade is not due to endowments of ICT, this supports the Ricardian model's theoretical predictions on patterns of trade. Most likely the analysis will find evidence that supports a combination of these two trade models. That being the case I would need a theory that can weigh the relative effects of endowments against returns to technology. I utilize the Blinder (1973) and Oaxaca (1973) decomposition methodology to disentangle the combined effects of endowments and technology on development and patterns of trade.

1. Introduction

This paper examines developing countries' ability to increase output capability and capacity through use of information and communication technology (ICT) in order to become competitive in international trade. I study the following questions in detail: (1) does ICT make developing countries more competitive in the export market and drive them towards a knowledge-based economy?[1] (2) Does a knowledge-based economy present an opportunity for some developing countries to bypass traditional and expensive brick and mortar industries (e.g. agriculture, mining, and manufacturing industries) that require large startup investments, thereby reaching the goal of capacity building and development faster?[2] (3) Does investment in ICT infrastructure stimulate trade in intellectual property, specifically, in the area of copyright related goods and services?

First, I specify a gravity model of international trade to estimate the impact that country characteristics have on international trade patterns. Next, I examine the error term of the bilateral trade model that may be correlated with one or more of the regressors. Tertiary, I account for the endogeneity of income in the gravity model by specifying instrumental variables (IVs) for income. Then I conduct a controlled experiment by indirectly estimating the impact ICT has on international trade and explaining the gap in trade attributed to ICT using Blinder (1973) and Oaxaca (1973) decomposition analysis. I utilize a cross-sectional dataset for a large sample of countries. This study presents an economic approach to measuring the impact that investment in ICT has on development and trade. The findings show that ICT contributes positively to economic development and is a significant determinant of international trade in copyright related industries.

1.1 Motivation

The motivation to examine the effect that ICT has on trade and development is twofold. First, the digital divide between developed and developing countries needs to be addressed for development and prosperity (see table 1 below).

Table 1: International Divide: Developed versus Developing Countries 2005 Two-Sample T-Test (unequal variances assumed)

Category:	P-Value
GDP	0.0000
Education	0.0000
Personal Computers	0.0000
Bandwidth	0.6130
Servers	0.0407
Bilateral Trade in Copyright Related Industries	0.0000

Source: World Development Indicators and United Nations Comtrade dataset (Units reported in Appendix A)

There is a significant difference (gap) across key indices that measure investment in ICT and the benefits from investment in ICT such as education and wealth. Note that there is no significant difference in bandwidth between developed and developing countries despite broadband access being a key policy issue at the United Nations. In addition, the growing number of industries impacted by ICT (as measured by sales) makes ICT investment attractive for developing countries that seek to diversify their economies (see figure 1 below).

Figure 1: World Exports of Information and Communication enabled Services in 2003 ($MM)
Source: IMF BOP Data

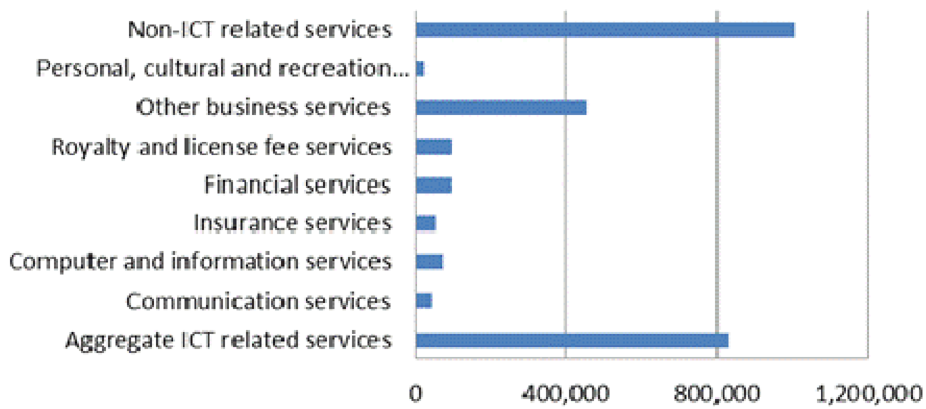


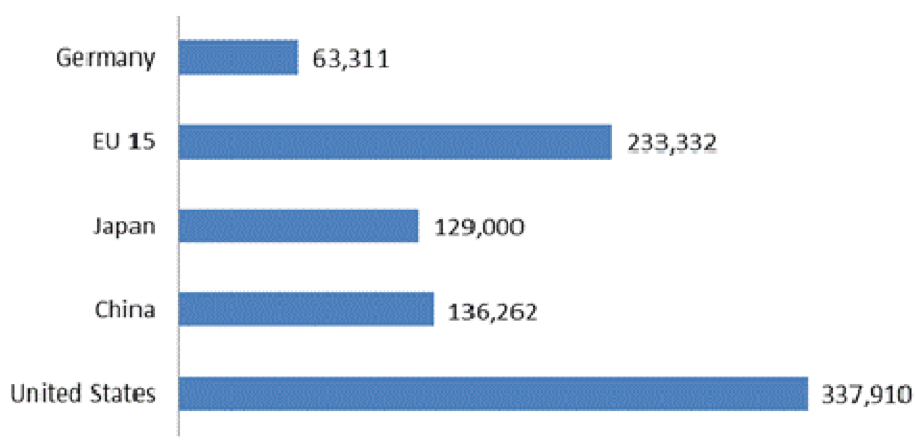
Figure 1 shows that the value of exports of aggregate ICT related services is approaching that of exports of non-ICT related services.[1] With the continued dissemination of ICT around the world, the value of exports of ICT related services will soon pass that of exports of non-ICT related services. The concurrent rise in globalization and information technology has spurned policy initiatives and research that supports the role of information technology in the form of intellectual property rights treaties and laws in promoting economic development (see Smith et al. 2009). An example of a successful ICT policy initiative (as measured by development and trade), was the policy embraced by The Clinton Administration in the United States early on: According to Samuelson and Varian (2001) – "The [Clinton] Agenda embraced information technologies as an enabling, and indeed as transformative, means of achieving a broad range of economic,

[1] Aggregate ICT related services includes an "other" category that consist of "merchanting, trade-related, operational leasing, legal, accounting, management consulting and public relations, advertising, market research and public opinion polling, research and development, architectural, engineering, agricultural, mining, and other on-site processing and services between related enterprise," (UNCTAD (2002) and IMF CD-ROM.

social, and political goals. The Agenda characterized the US as having become primarily an information based economy and asserted a bright future for communications and information industries." Global organizations like the World Intellectual Property Organization (WIPO, 2003), United Nations Educational, Scientific and Cultural Organizations (UNESCO, 2005; 2006), United Nations Conference on Trade and Development (UNCTAD, 2010) have also embraced policies and research that advocate investment in ICT as a means to economic growth and development.

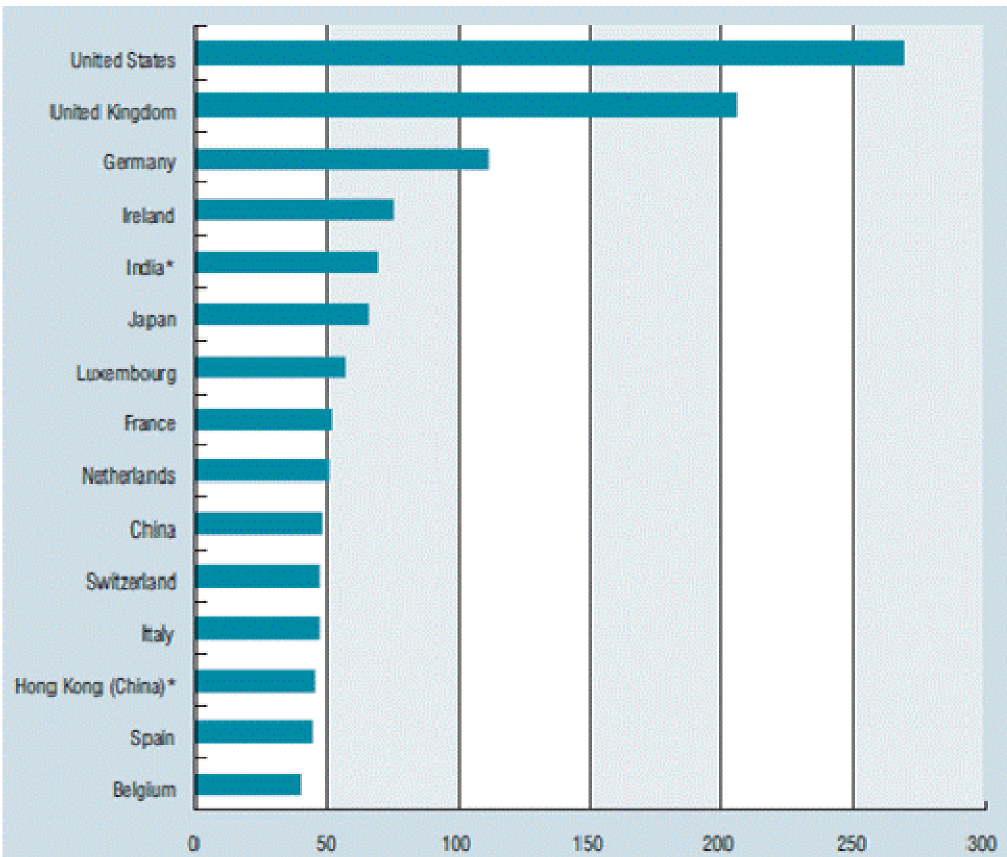
Gross domestic expenditure on R&D can be a proxy for the next generation technologies that will drive economic growth and development. In 2006, the US gross domestic expenditure on R&D was greater than the combined expenditures of Germany, China and Japan (see Figure 2 below).

Figure 2: Gross Domestic Expenditure on R&D 2006 ($MM and PPP)
Source: OECD



China was the sixth largest economy in 2005 and was also considered a developing country that same year. The US spent roughly 250% more than China on R&D in 2006. The findings shown in table 1 and figures 1 and 2 frame a development problem due to lack of investment in assets that increase capacity in the areas of trade and presents a comparative advantage. The impact (cost/benefit) investment in ICT has on development and trade can be measured in dollars; particularly by exports of ICT enabled services (see Figure 3 below).

Figure 3: Top 15 Exporters of IT and ITC enabled Services 2007 ($BB)
Source: UCTAD based on data from the IMF



The US earned 5 times more than China on its exports of IT and ICT enabled services in 2007. R&D theory suggests that investment in R&D leads to new technology and the benefits of new technology can be shared (in the form of spillovers) with firms that did not make the initial investment in new technology (see UNCTAD 2002). In this setting spillovers are a positive externality that can drive down the cost of new technology by foregoing the investment in the R&D phase for developing countries to compete in IT and ICT enabled exports. Thus direct investment and foreign direct investment in ICT presents an opportunity for developing countries to reach the goal of capacity building and development more rapidly than investment in mining and manufacturing, where startup capital is a burdensome fixed cost to cover for most developing countries.

1.2 Contributions

In this study I focus on copyright related industries that are impacted by ICT. I answer questions 1, 2 and 3 using a counterfactual argument: If developing countries have the same ICT investments (i.e. endowments of physical capital and human capital) as developed countries how much of the gap in trade and development between developed and developing countries can be attributed to investment or (lack of investment) in country level endowments and technology in the form of ICT?[3] To answer this question I specify an aggregate production function based on factors of production variables used in Smith et al. (2009) which finds education, personal computers, servers and bandwidth have a positive and significant impact on GDP. This model follows closely the production function used by Cyrus (2002) to correct for endogeneity of income in the gravity model of bilateral trade that is grounded in the factor accumulation variables from the augmented Solow model of Mankiw, Romer, and Weil (1992). Essentially Cyrus (2002) provides the foundation for the first-stage equation being the determinant of income (as in the neoclassical growth equation).

Next, I specify a gravity model of international trade to estimate the impact that country characteristics have on international trade patterns under the premise that trade between two countries is analogous to the gravitational force between two objects – country size (income) is a positive force for trade and distance between two countries (i.e. transportation cost) is a negative force against trade. The antecedents of the model are found in Tinbergen (1962), Polyhonen (1963), and Linnemann (1966).

Last, I test the hypothesis that the gap in trade in copyright related material between developed and developing countries can be explained by the lack of direct and foreign direct investment in ICT. This can be assessed using decomposition analysis to simulate the effect that ICT endowments and technology have on economic development and trade in copyright related industries.[4] Decomposition analysis was originally proposed by Blinder (1973) and Oaxaca (1973), who decomposed wages (income) between different socio-economic groups. Blinder-Oaxaca decomposition analysis can validate cost and benefit assumptions about investing in ICT while controlling for country level endowments and technology. For example, decomposition analysis can measure what it would be like if developing countries had the same level of investment in ICT as developed countries and the impact equal investment in ICT would have on growth and trade. As it stands today we must use simulation to test the counterfactual, which makes it difficult to definitively prove/disprove. Blinder-Oaxaca (1973) decomposition analysis allows us to test the counterfactual. Thus, the contribution of this inquiry is a methodology that can be used to measure the causal relationship between ICT, development and trade since a controlled experiment is not feasible.

If this study finds that relative income shares (returns) to ICT are the same in both developed and developing countries and the gap in trade is due to endowments of ICT, this supports the theoretical underpinnings of the Heckscher-Olin (H-O) model, which states that developed countries have a comparative advantage in ICT enabled trade because they have larger endowments of ICT. Thus a policy recommendation for developing countries that is congruent with the theoretical underpinnings of the H-O model is to invest in ICT in order to close the gap in ICT enabled trade. On the other hand – if this paper finds that relative income shares (returns) to ICT are different between developed and developing countries and the gap in trade is not due to endowments of ICT – this supports the theoretical underpinnings of the Ricardian model that says developed countries have a comparative advantage in ICT enabled trade because they are more efficient in production (i.e. higher returns to ICT). Thus a policy recommendation for developing countries that is congruent with the underpinnings of the Ricardian model is not to invest in ICT to close the gap in ICT enabled trade. Most likely the analysis will show evidence that supports a combination of both models; this being the case, the study would need to use a statistical model that can separate and weigh the relative effects endowments have against returns to technology. Furthermore, if the study finds no statistical difference in endowments and returns to ICT across countries it begs the question, "why is there a lack of direct and foreign direct investment in ICT infrastructure and industries in many developing countries?" The overall goal is to provide empirical evidence of the effect ICT has on development and trade. I start by surveying the literature of ICT for development.

1.3 Survey of ICT for Development Literature (OECD, UNCTAD, ITU)

Over the past decade, numerous studies on the connection between technology, growth, development, and trade (the new economy) have been conducted. Specifically, as it relates to ICT for development, the OECD and the United Nations (UN) have analyzed these studies, the literature and data, and made recommendations for countries to invest in ICT in order to increase their growth and development. The OECD and UN reports adequately summarize the vast literature on ICT for development and the "new economy" as a means for development. Specifically, I use a series of reports published by the OECD and UN (and related agencies) as the background literature for this study on the impact ICT investment has on growth, development and trade. Last, I utilize the approach of van de Walle and Gunewardena (2001), who used the Blinder (1973) and Oaxaca (1973) decomposition methodology to analyze the impact of differences in endowments, and of the returns to those endowments, on growth and development. The literature cited in this paper provides the analytical framework for investigating the connection between ICT, growth and development.

The ICT literature follows a distinct pattern over time: (1) establishing a relationship between ICT and growth and development, (2) explaining why countries had varying degrees of success in the "new economy," and the role ICT investment played in the variation of success, and (3) applying developed countries' findings (e.g. to invest, educate, and regulate) to developing countries and making policy recommendations based on this application in order to increase economic growth and reduce poverty. This pattern of inquiry provides an outline for the literature review.

Analysis of the impact of ICT has on economic growth and development started in 2001 with a series of technical and analytical publications by the OECD Directorate for Science, Technology and Industry. These publications addressed issues of data, methodology and empirical analysis of ICT investment and economic growth and development in the 1990s. The basis for the studies was the 2001 Ministerial report, "The New Economy: Beyond the Hype," which concluded that ICT would be the driving force behind rapid growth and productivity gains in the 21st century. Further examination revealed disparate results from investment in ICT. Colecchia and Schreyer (2001) investigated the disparity by comparing the impact of ICT capital accumulation on output growth in Australia, Canada, Finland, France, Germany, Italy, Japan, the United Kingdom, the United States. Using National Accounts data that covered a 20 year time period, they found that ICT contributed between 0.2 and 0.5 percentage points per year in economic growth; this growth picked up in the latter part of the 90s, rising somewhere between 0.3 to 0.9 percentage points per year. They concluded that dissemination of ICT is essential and needs to exist in an economic framework to optimize growth. This is to say, the existence of an ICT manufacturing sector is not the only way to benefit from technology.

The OECD published a second series of papers that focused on ICT and economic growth and development from the perspective of industries and firms. This report was a follow up to the previous report. It was a response to the US Secretary of Commerce's request for further proof of the benefits of ICT investment. An OECD-led team utilized firm-level data and incorporated new evidence on e-commerce. The findings supported the hypothesis that investment in ICT stimulates productivity, growth and development. However, the findings also showed that gains from ICT in the form of growth and productivity are asymmetric across countries:

> "Despite the importance of ICT, there continues to be marked difference in the diffusion of ICT across OECD countries. New OECD data show that the United States, Canada, New Zealand, Australia, Nordic countries and the Netherlands typically have the highest rates of diffusion of ICT. Many other OECD countries lag in the diffusion of ICT and have scope for greater uptake. It is likely that the largest economic benefits of ICT should be observed in countries with high levels of ICT diffusion. However, having the equipment or networks is not enough to derive economic benefits. Other factors, such as the regulatory environment, the availability of appropriate skills, the ability to change organizational setups, as well as the strength of accompanying innovations in ICT applications, affect the ability of firms to seize the benefits of ICT. Consequently, countries with equal ICT diffusion will not always have similar impacts of ICT on economic performance," (OECD 2003).

The early OECD reports made the case for investing in ICT by showing measured growth in productivity gains attributed to ICT accumulation. The report findings were limited in scope to OECD member countries. To date the OECD continues to provide updated reports on ICT for development.

In 2002 the United Nations Conference on Trade and Development (UNCTAD) Division on Investment, Technology and Enterprise Development started to publish a series of papers on the benefits of foreign direct investment in technology, transnational corporations disseminating technology abroad, and enterprise development based on technology. The first report in the Technology for Development Series, "Partnerships and Networking in Science and Technology for Development," focused on understanding the relationship between technology and development. The early findings suggested that open trade presents an opportunity for developing countries to access market technology in advanced countries. Furthermore, these business interactions in the private sector were a growing source of technological transfer. For example, transnational corporations increasingly used various kinds of cooperation agreements, such as joint ventures, joint research and development (R&D) agreements, technology exchange agreements, co-production agreements, and direct minority investments and sourcing relationship to increase profitability. These types of contractual agreements helped developing countries access new technology. The report hoped to promote international cooperation on science and technology among developed and developing countries by arguing that foreign firms operating in developing countries and emerging markets had succeeded in significantly increasing their technological capabilities and competitiveness through partnering, networking and trade with domestic partners. In the end, the report cautioned policy makers and analysts not to form expectations for developing countries based on developed countries' experience with ICT.

The second paper in the UNCTAD series, "Changing Dynamics of Global Computer Software Industry: Implications for Developing Countries," was published in

2002 and explored the implications of the computer software industry's potential to become one of the most internationally dispersed high-tech industries and outlined implications for developing countries. The computer software (services) industry is an example of a knowledge-based industry that has been dominated by developed economies, both in terms of demand and supply even with the relatively low barriers to entry and capital requirements. However, a growing computer software (services) industry provides an opportunity for developing knowledge-based economies that lead to economic development. Utilizing earlier OECD studies as evidence, ICT was accounting for an increasing proportion of Gross Domestic Product (GDP). Specifically, telecommunications, computer and information services, finance, insurance, royalties and other business services were now recognized as being impacted by ICT and were growing industries. This provided further evidence that ICT was a means to sustainable economic development, thus, meeting the goal of market diversity. The report also emphasized the growing need to address the disparity in the expansion of the computer software (services) industry in developing countries and offered the poor distribution of computers within developing countries as evidence. The report concluded that investment in a computer software (services) industry is conducive to economic development, especially in the area of exporting goods and services that range from low skill data entry jobs to high skill programming work. This leads to the third report.

The third report in the UNCTAD series, "Investment and Technology Policies for Competitiveness: Review of Successful Experiences," published in 2003, emphasized technology transfers and capacity building as a development strategy. Underlining this strategy was the need for developing countries to improve their ability to learn (educate) in order to take full advantage of technology transfers (spillovers) that come from FDI. It confirmed that the relationship between education and FDI is the key to technological progress in developing countries that lack direct investment in R&D and capacity building. The 2003 report also recommended developing countries take a technological capabilities approach (i.e. assess their current level of expertise and plan accordingly) to industrial development and trade policy because large differences in competence to interact with simple labor-intensive technology is expected between developing countries in the capability approach to development and trade. A contextual argument for taking a technological capabilities approach to development and trade was illustrated in the report:

> "Countries with similar "endowments" and openness to technology flows can have different kinds of comparative advantage and different patterns of evolution over time, depending on the national learning system. Traditional determinants of comparative advantage do remain relevant – but through their effects on learning, when their assumptions conform to technological realities."

This explained why significant variations in export performance between low-wage countries in simple manufacturing could exist even after differences in location, endowments, and trade policy were taken into account. Outcomes like this could only happen if there were differences in national learning i.e. technological capability (see Lall 2001). After taking into account variations in human capital the report suggested that ICT was at the core of industrial competiveness. The report also pointed out the role of FDI, in the form of research and development, licensing, information and communication technology infrastructure and human capital, has on the structural determinants of industrial competiveness and comparative advantage. It highlighted FDI as a means of bringing new technology to developing countries and the need for developing countries to improve their ability to absorb (transfer) new technology. Notwithstanding the benefits of FDI, the report concluded that the continuation of national development projects as a strategy for identifying comparative advantage for export-led development needs to be subsidized because of the risks associated with providing large financial appropriations to fill the gap in investment that the market could not remedy. Put another way, market imperfections were a significant factor in determining ICT investment in developing countries. The structural risk associated with emerging markets, in addition to lack of ICT investment and intellectual property rights, may contribute to the technological divide between developed and developing countries.

Starting in 2006 UNCTAD released a second series of reports titled: "Information Economy Report." The reports supported previous UNCTAD efforts to establish a link between ICT and development and focused more on the digital divide. This time part of their information gathering effort was to solicit (rather than survey) studies on the impact that ICT has on development. This approach was essential to addressing the potential for measurement error that comes from collecting data from different countries and then aggregating the results. The collection of statistical indicators on the macroeconomic impacts of ICT with a special focus on developing countries was carried out in 2005. The report used the Info-density composite index developed by the Orbicom Digital Divide Initiative. The info-density composite index is specified as a production function of an economy composed of capital and labor that is enhanced by ICT. The model was a log-log model with per capita GDP as the dependent variable; and population growth, openness measure, inflation, gross capital formation weighted by GDP (a proxy for investment), and the Orbicom info-density index as the independent variables. The findings showed that investment in ICT led to growth and development, and that ICT was a viable option to achieve this outcome for developing countries.

In 2008 UNCTAD published its second report under the series "Information Economy Report 2007 - 2008: Science and Technology for development: the new paradigm of ICT." This report looked at the connection between technological innovation and its ability to improve the general welfare of developing countries, which takes the form of enterprise competitiveness. The report also supported government policy intervention in developing countries to nurture the ICT sector. The authors based this recommendation on the need for international technology transfer and knowledge-sharing that can be achieved through harmonization of intellectual property rights regimes, open access to knowledge and international trade agreements. However, the process of technology transfer is necessary but not sufficient for developing a competitive ICT sector that will help bridge the income gap between developed and developing countries. They based this on two competing macroeconomic growth theories:

> "The two schools, neoclassical and endogenous, differ in the analysis of the duration of the economic impact of technology. The neoclassical approach takes the view that technological progress has only a transitory effect on the rate of growth, but a lasting effect on the level of per capita income, which will move to a higher new steady state level. The endogenous growth theory (or at least some version of it) implies a

permanent effect on the long-term rate of growth. Under the neoclassical approach, the economic development of countries at different levels of development will converge towards the same steady state level (the catch-up phenomenon), given conditions of perfect competition and free flow of technology between countries, while under the endogenous growth approach, structural characteristics implying different endogenous technological capabilities results in a persistent divergence of growth paths, which require government [policy] interventions to address structural problems, going beyond the simple recipe of increasing savings and investment."

The report's focus was to measure the impact ICT has on information dissemination to promote better livelihoods. E-commerce was noted as a growing sector that could benefit from innovation policies and stricter intellectual property rights regimes and harmonization across countries through international organizations and treaties (e.g. World Trade Organization on Trade Related Aspects of Intellectual Property Rights – TRIPS agreement). By this point it had been well established that investment in ICT and technological innovation were drivers of growth, development, and trade. Nevertheless the income gap between developed and developing countries remained a structural inhibitor to developing countries investing in an ICT sector.

In 2010 UNCTAD published its third report under the series "Information Economy Report 2010: ICTs, Enterprise and Poverty Alleviation." This report addressed the potential of ICT to contribute to the fight against poverty. It asserted that, for the first time, there were realistic opportunities for rural inhabitants (e.g. farmers, fisherman, as well as entrepreneurs) in low-income countries to access data and information via ICT. Mobile technological innovations (in the form of applications) by urban entrepreneurs were advancing the livelihoods of rural inhabitants. For example, applications on smart phones that can measure nutrient levels in agricultural cropland in fertilizer deprived countries. The 2010 report stressed the connection between poverty, information, and enterprise; and identified ICT as an important tool in fostering information sharing. Poor people often lack access to information that may better their livelihoods (e.g. weather reports, market prices, income and earnings reports, employment opportunities, etc.). Such lack of information puts poor people at a market disadvantage. The main conclusion of the report was that information plays a key role in "(a) informing and strengthening the short-term decision making capacity of the poor themselves; and (b) informing and strengthening the longer-term decision making capacity of intermediaries that facilitate, assist or represent the poor." Furthermore, the role ICT plays in poverty reduction lies in enterprise, and the introduction of an ICT sector can contribute to growth, development, and trade.

The International Telecommunications Union (ITU), a UN agency, is charged with negotiating telecommunications space and promoting investment in ICT as a development policy for UN member countries. ITU is working in conjunction with UNESCO to study the impact ICT has on development – specifically in the area of broadband technology. After the Geneva World Summit on Information Society (WSIS) in 2003, and the Tunis WSIS in 2005, ITU started measuring ICT investment-targets. Annually they published the World Telecommunications/ICT Development Report (WT/DR) on ICT investment targets and statistics. Stark investment growth in cellular technology and modest to meager investment growth in broadband technology was a consistent theme in the reports. The director of the Telecommunications Bureau ICT stated:

> "Too many schools in developing countries continue to be deprived of access to the internet, and three-quarters of the people in the world are not yet online. Only a very small proportion of the information hosted by libraries and archives has been digitized, and even less is available online… [also] the persistent broadband divide, which policy makers need to tackle urgently [is an inhibitor]…most people in the developed countries enjoy internet access with a high-speed connection, broadband penetration rates in the developing world stood at a meager 3.5 per cent," (World Telecommunications/ICT Development Report 2010).

The WT/DR report relied on policy goals in the Geneva Plan of Action to measure success in the area of ICT for development. But few, if any, had measured the effects comparative advantage has on the gap in ICT related trade when explaining the gap in ICT-investment between developed and developing countries. The nuance of comparative advantage needs to be considered when allocating ICT resources efficiently for economic growth and development. The theory of perfect competition and profit maximization suggests that firms and countries behave in a way to maximize their return on investment. Theoretically, investment in ICT will happen in areas of the economy that will yield the highest return on investment. Under these circumstances it may not be surprising that developing countries do not have a comparative advantage over developed countries because developing countries lag behind developed countries in ICT-related investment for development. This perspective has to be balanced with the perspective that ICT related investment can increase growth and development at a higher cost. Put another way, developing countries may experience short-term losses (non-comparative advantage) at the beginning of investment and long-term gains (comparative advantage) at the end of investment.

Based on the OECD, UNCTAD, and ITU reports – investment in ICT will make developing countries more competitive domestically and abroad. Economic liberalization in developing countries will also help developing countries realize their comparative advantages. This traditionally takes the form of inherited endowments such as natural resources and cheap unskilled labor. According to the UNCTAD 2003 report, relying on inherited endowments will not allow them to take advantage of the more dynamic market opportunities that lead to sustainable growth and development presented by investment in ICT. Thus, developing countries "may suffer from long-term marginalization, having to export more products facing static or devolving markets to import foreign services and products," (Investment and Technology Policies for Competitiveness: Review of Successful Experiences 2003).

1.4 Measuring the Returns of ICT for Development

Examining how differences in factor endowments and factor returns to endowments impact consumption and income, economists have found that disparities in income can be explained by differences in returns to factor endowments (see UNCTAD 2003 report). This can be translated into a comparative advantage for the group that benefits from these differences. One study in particular, using a technique first developed in the field of labor economics, mentions the phrase comparative advantage in the context of development. Dominique van de Walle and Dileni Gunewardena (2001) show how differences in returns to factors of production effect economic development in Viet Nam. They demonstrate how differences in returns to key factors of production can result in income disparities using the well-known Blinder (1973) and Oaxaca (1973) decomposition method, which is designed to estimate two earnings equations and use the estimated parameters along with the inter-group means of economic characteristics (endowments) to measure how differences in the estimated parameters and in the inter-group means can affect wages and income. Van de Walle and Gunewardena's application of the Blinder-Oaxaca decomposition analysis has policy implications beyond labor economics. Their work puts forward the idea that a community (country) can benefit in the long-run despite differences in returns to comparable factors of production in the short-run. They suggest the group that does not benefit from the disparity in the primary market develops a comparative advantage, and if not, an absolute advantage in secondary markets where they may maximize their return on investment (e.g. illegal black economies, textiles, manufacturing, etc.). Van de Walle and Gunewardena say the result of low income (minority) groups developing comparative advantages in secondary markets with low growth and development potential can further exasperate wealth inequality in the long-run. Thus an economic development policy should consider comparative advantage in the short-run and long-run. In this context, differences in the returns to productive factors across countries should not deter investment in industries that may have a non-comparative advantage in the short-run while having a comparative advantage in the long-run. The microeconomic and macroeconomic policy implications of the Van de Walle and Gunewardena sets up a natural cost/benefit analysis framework to study the net return on investment for communities and countries that receive lower return on education and technology that are key factors to economic growth and development.

The field of labor economics has evaluated the theoretical underpinnings of the Blinder-Oaxaca decomposition method as a cogent tool for parceling out the effect disparities between groups based on differences in factor endowments and returns to factor endowments. Conversely, little theoretical and methodological analysis has been done at the macroeconomic level, thereby providing an opportunity to investigate its application to trade and development theory. In this paper I test that investment in ICT will be a source of growth and development. Evaluation of ICT related trade as an economic growth, development and trade policy will require a framework that can weigh the benefit of investing in industry where a country does not have a comparative advantage and investing in industries that have short-run losses and long-run gains. I argue that Blinder-Oaxaca decomposition analysis offers a framework that can be used to weigh net gains from investment in ICT for trade and development. The outcome of the study is a cost/benefit analysis that takes into account issues of comparative advantage in

ICT-related trade. I intend to contribute to the discussion started by the OECD and ITU – that ICT and the knowledge-based economies present new opportunities for developing countries.

2. Model/Framework

2.1 Development Specification:

The theoretical framework for analyzing ICT and development is macroeconomic theory. I assume all technology has constant returns to scale. I utilize the following aggregate production function:

$$Y = \lambda F(K, L) \qquad (1)$$

where Y is gross domestic product (GDP); and λ is a country level parameter that captures efficient use of technology, and *K* (capital) and *L* (labor).

I modify this standard production function by detailing the factor inputs. First I define labor (*L*) as human capital. Second, I define capital (*K*) as ICT including personal computers, bandwidth and servers.[2] These unique forms of ICT transmit and store intellectual property such as blueprints, financial data, and software. These modifications give the following equation:

$$Y = \lambda F(K_1, K_2, K_3, L) \qquad (2)$$

where K_1 is personal computers, K_2 is bandwidth, K_3 is servers, and L is human capital.

[2] Note: there is a misspecification of the aggregate production function. However, I am following the specification of the production function originally outlined in the Smith et al. (2009) paper. In section 2.2 I examine the theoretical and estimation consequences of omitted variable bias (see section 2.2 and Appendix B for results related to the misspecification of the aggregate production function).

Next, I rewrite the aggregate production equation in per capita form by dividing all terms by population. Using the common practice of expressing per capita terms in lower case letters produces the following equation:

$$y = \lambda F(k_1, k_2, k_3, l) \qquad (3)$$

where k_1 is personal computers per capita, k_2 is bandwidth per capita, k_3 is servers per capita, and l is human capital per capita.

Next, I rewrite the aggregate production equation in Cobb-Douglas form as:

$$Y = \lambda k^{\alpha 1} k^{\alpha 2}\, k^{\alpha 3}\, l^{\alpha 4} \qquad (4)$$

where each alpha (α) is a respective share of income and k and l have constant returns to scale. In theory α is the fraction of total output that goes to compensate the respective factor and these shares are positive.

To derive the statistical specifications for the study, I define the aggregate production function in Cobb-Douglas form for each country j and apply the definitions of factor inputs detailed above. This specification allows me to focus on the returns to technological endowments. For estimation purposes I write the aggregate production function in log-linear form:

$$\ln(Y) = \alpha_0 + \alpha_1 \ln(Computers_j) + \alpha_2 \ln(Bandwidth_j) + \alpha_3 \ln(Servers_j) + \alpha_4 \ln(Human\ Captal_j) + \varepsilon_j \qquad (5)$$

where $\alpha_0 = \ln(\lambda)$, and ε_j is the error term, and j indexes the country.

<u>Parameter Specification</u>

I expect the parameters in the statistical specification to be positive and significant based on the underlying theory that the coefficients are interpreted as shares of the total output that goes to compensate a factor input (see table 2 below).

Table 2: Expected Signs of Parameter Estimates of Development Equation

Variable:	Shares	Expected Sign
Constant	α_0	≥ 0
Personal Computers	α_1	≥ 0
Bandwidth	α_2	≥ 0
Servers	α_3	≥ 0
Human Capital	α_4	≥ 0

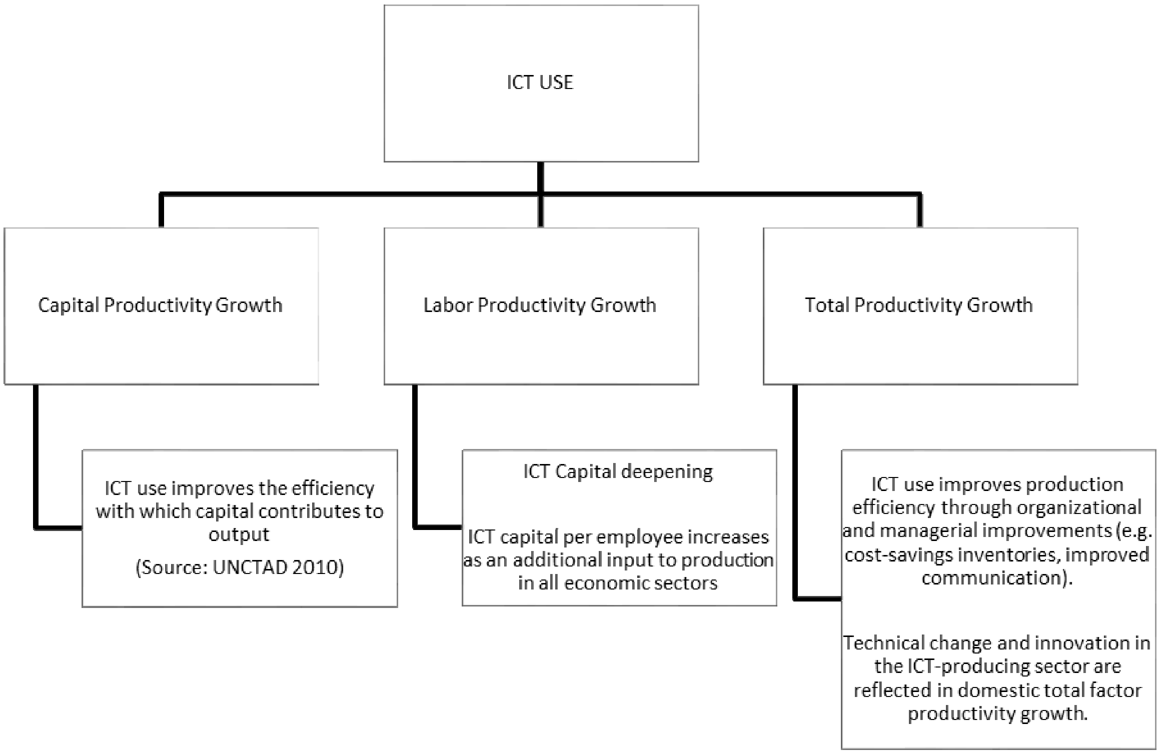
Hypothesis 1: A country's ICT is positively related to its economic development.

Hypothesis 1 is related to question (1) – "Does information communication technology (ICT) make developing countries more competitive in the export market and drive them towards a knowledge-based economy?" A positive and statistically significant coefficient on ICT will support Hypothesis 1 and help demonstrate the impact ICT has on the export market, down the line.

2.2 Estimation Problems with the Development Equation: Omitted Variable Bias

Suppose that ICT in the development equations is correlated with unskilled labor and non-ICT capital and the latter variables are left out of the estimated development equation (See Table 3a below).

Table 3a:



The relationship between ICT use and non-ICT related capital presents a grey area between the two types of capital. Taking the conditional expectation of development given ICT and educated labor (E[Y| educated and uneducated labor, ICT, non-ICT]) will place the omitted variables in the error term causing ICT to be endogenous. The direction (+/–), magnitude, and consequence of the bias needs to be addressed. In some cases it is acceptable to assume the bias has a zero impact on the estimated parameters if a constant term is included in the estimated development equations (see Greene 2003 and Wooldridge 2002). In this study it is assumed that the constant term in the development equation is a country level parameter that captures efficient use of technology (λ). This follows production theory and the work done by Solow (1958). In addition, the methodology in this study closely follows the growth accounting and productivity methodology outline in the OECD 2001 report, which is also based on the work done by Solow (1958). In the OECD report capital services are provided by *K* different types of assets, of which *K1* are ICT assets and *K2* are non-ICT assets ($K = K1 + K2$). Within the growth accounting and productivity methodology, decomposition of the growth equation is: $d\ln Q = L d\ln L + K d\ln K1 + K d\ln K2 + d\ln A$, where *L*, *K1*, and *K2* are elasticities on labor, ICT capital, and non-ICT capital. Under constant returns to scale cost shares are equal to income shares and sum to unity. Furthermore, *w* is the average wage per hour of labor input, *r1* is the cost of a unit of ICT capital services, and *r2* is the cost of non-ICT capital services; they represent the prices of inputs so that *wL/PQ* is the income share of labor and *r1/PQ* and *r2/PQ* are the income shares for ICT and non-ICT capital. The $d\ln A$ term in the growth accounting and productivity framework is the average rate of growth of factor inputs and is a multi-factor productivity (MFP) term. In this study λ is a country level parameter that captures efficient use of technology and is a MFP term ($\lambda = d\ln A + wL/PQ + r2/PQ$). The aforementioned is purely a theoretical derivation and does not completely eliminate omitted variable bias. The direction and magnitude of the bias has to be taken into consideration when using the results for applied economic analysis. With this being said, deviations in measuring the return (value added) that ICT investment has on growth and development will affect the measurement of economic welfare attributed to ICT investment. The impact of omitted variable bias ($\alpha_k = \Gamma_k + \Gamma_Z\delta_k$) in this context is assumed to be an overestimate of the ICT parameters and increased significance of the estimated parameters. Note: omitted variable bias can switch the signs on the estimated parameters in the regression model. The estimated parameters in this study conform to theory and have the right sign.

To test whether the omitted variable problem has a significant impact on the Smith et al. (2009) results I specify an aggregate production function to include ICT and non-ICT related capital. The first set of tests include ICT and non-ICT related financial capital variables that measure the net value added to an economy by industry (e.g. agriculture, industrial, manufacturing, and service industries). Estimating the aggregate production functions with the net value added variables is similar to what UNCTAD specified in the reports titled "Information Economy Report." The reports establish a link between ICT and development. The model was a log-log model with per capita GDP as the dependent variable, and gross capital formation weighted by GDP (a proxy for investment) along with demographic variables and a digital divide index as the independent variables.

An additional justification for using the net value added to an economy by industry variable is because including stock variables like the ones for ICT would be numerous and burdensome for estimation. Thus, under these circumstances using variables such as the net value added to an economy by industry can capture the total investment in inputs by a particular industry. The net value added to an economy is the total value of output minus the total value of inputs. Put another way, total value of output = net value added + total value of inputs.

The second set of tests include ICT and non-ICT related capital stock variables in an economy by industry, e.g. arable land, tractors per 100 sq. km of arable land, livestock production, the percentage of paved roads, the volume of goods transported by roads and rail measured in million metric tons times kilometers traveled, and the number of domestic companies listed on a country's stock exchange excluding investment firms, and mutual funds. In addition, I specify an aggregate production function to include ICT and non-ICT related variables in the energy and mining sector such as energy production and energy production minus use to measure the impact natural resource endowments have on an economy and returns to ICT. The energy and mining variables are composite variables that include petroleum, natural gas, coal, combustible renewables, and primary electricity all measured in kilotons of oil equivalent.

The last set of tests includes different measurements of human capital to test whether different measures of human capital impact the returns to ICT related capital. This provides context for evaluating the impact non-ICT related labor has on development and returns to ICT related capital. Additionally, using different measurements of human capital will help sift through the impact quality of educational institutions have on returns to ICT related capital. First, I estimate the models above using an education index which measures the weighted sum of adult literacy and gross education enrollments. Second, I estimate the models using a human development index (which is a combination of life expectancy, quality of life and knowledge). Tertiary, I estimate the models using labor market participation rates, which measures all labor (of individuals aged 15 and older) used in the production of goods and services (which can be considered a labor stock variable).

The result from the first set of tests using the net value added variables suggests the Smith et al. (2009) model does not suffer from omitted variable bias. I conducted a *z* test on the ICT only production function estimates and the aggregate production function estimates that includes ICT and non-ICT related capital using the net value added variables. The results show no significant difference between the ICT related capital estimates (see table 3b). Thus, the results from the first set of tests using the net value added variables support the Smith et al. (2009) approach.

Table 3b: Country Estimates of Development Equation
(Aggregate Production Function)

Variable:	Estimates
Constant	7.21**
	(0.47)
Agriculture Net Value Added	-0.20**
	(0.06)
Industrial Net Value Added	0.13**
	(0.07)
Personal Computers	0.22**
	(0.06)
Bandwidth	0.10**
	(0.02)
Servers	0.04*
	(0.02)
Human Capital	0.42*
	(0.22)
R^2	0.9215
N	108

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. *Significant at 10% level. All variables are in logs.

It should be noted there are sizable disparities in the estimated coefficients between the two models. The smallest disparity in the estimated coefficients is the difference in the estimation of the human capital variable. The difference between this variable estimation is 25 percent of the estimated coefficient in the aggregate production function model. This should be taken into account since I am measuring return to ICT related capital and the application of the results in cost benefit analysis will be sensitive to the misspecification of the aggregate production function.

The second set of tests using capital stock variables in the form of arable land, tractors per 100 sq. km of arable land, livestock production,[3] the percentage of paved roads, the volume of goods transported by roads and rail, the number of domestic companies listed on a country's stock exchange, and natural resource endowments are capital stock investments that are essential for growth in capital intensive industries such as agriculture, industrial manufacturing and mining, and other heavy factory industries that are dependent on a domestic stock exchange to raise capital for future growth.

The results from the aggregate production function estimation that includes arable land, tractors per 100 sq. km of arable land, and livestock production suggest the Smith et al. (2009) model does not suffer from omitted variable bias. The arable land variable has a statistically insignificant effect on per capita GDP. The results for arable land are not shown. Tractors per 100 sq. km of arable land had a significant impact on per capita GDP. In addition, I conducted a z test on the ICT only production function estimates and non-ICT related capital estimates that include tractors per 100 sq. km of arable land. The results show no significant statistical difference between the ICT variables when comparing the two models.

[3] Livestock production is a composite variable that includes meats and milk from all sources, dairy products such as cheese, and eggs, honey, raw silk, wool, and hides and skin," (see World Bank).

Table 3c: Country Estimates of Development Equation
(Aggregate Production Function)

Variable:	Estimates
Constant	7.09**
	(0.32)
Tractors per 100 sq. km of arable land	.112**
	(0.03)
Personal Computers	0.18**
	(0.08)
Bandwidth	0.11**
	(0.04)
Servers	0.05*
	(0.03)
Human Capital	0.58**
	(0.29)
R^2	0.9283
N	55

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. *Significant at 10% level. All variables are in logs.

The results from the aggregate production function estimation, which includes livestock, are similar to the results reported above. I conducted a z test on the ICT only production function estimates and the non-ICT related capital estimates that includes livestock production. The results show no significant difference between the ICT variables when comparing the two models.

Table 3d: Country Estimates of Development Equation
(Aggregate Production Function)

Variable:	Estimates
Constant	7.74**
	(0.44)
Livestock Production	0.61**
	(0.03)
Personal Computers	0.23**
	(0.07)
Bandwidth	0.09**
	(0.03)
Servers	0.13*
	(0.04)
Human Capital	0.49**
	(0.21)
R^2	0.9043
N	107

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. *Significant at 10% level. All variables are in logs.

Next, I specify an aggregate production function to include ICT and non-ICT related capital stock variables in the energy and mining sector. I estimate models using energy production and energy production minus use to measure the impact trade in energy has on an economy and returns to ICT. The energy production variable is a composite variable that includes petroleum, natural gas, coal, combustible renewables, and primary electricity – all measured in kilotons of oil equivalent. The role natural resource endowments play in development has been well documented. In addition, energy production is vital to developing a knowledge based economy. I conducted a z test on the ICT only production function estimates and non-ICT related capital estimates that include energy production and energy production minus use. The results show no significant difference between the ICT variables when comparing the two models.

Table 3e: Country Estimates of Development Equation
(Aggregate Production Function)

Variable:	Estimates
Constant	7.43**
	(0.29)
Energy Production Minus Use	0.03**
	(0.02)
Personal Computers	0.20**
	(0.07)
Bandwidth	0.15**
	(0.03)
Servers	0.07**
	(0.02)
Human Capital	0.66**
	(0.27)
R^2	0.9655
N	91

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. *Significant at 10% level. All variables are in logs.

The industrial manufacturing and mining sector are heavy factory industries (i.e. factories that use heavy equipment to produce goods) that depend on extensive logistical operations to deliver heavy physical goods (inputs and outputs) to market. Investing in logistical infrastructure is necessary to compete in heavy factory industries. For example, transport of heavy machinery to a factory has to be done on paved roads, railways, and/or navigational waterways. I estimated an aggregate production function that includes the percentage of paved roads and the volume of goods transported by roads and rail. I conducted a *z* test on the ICT only production function estimates and non-ICT related capital estimates that include the percentage of paved roads. The results show no significant difference between the ICT variables when comparing the two models.

Table 3f: Country Estimates of Development Equation
(Aggregate Production Function)

Variable:	Estimates
Constant	7.15**
	(0.46)
Percentage of Paved Roads	0.03
	(0.02)
Personal Computers	0.40**
	(0.06)
Bandwidth	0.07**
	(0.03)
Servers	0.06*
	(0.03)
Human Capital	0.26**
	(0.13)
R^2	0.9655
N	37

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. *Significant at 10% level. All variables are in logs.

Additionally, I conducted a z test on the ICT only production function estimates and non-ICT related capital estimates that include the volume of goods transported by roads and rail. The results show no significant difference between the ICT variables when comparing the two models.

Table 3g: Country Estimates of Development Equation (Aggregate Production Function)

Variable:	Estimates
Constant	7.30**
	(0.33)
Volume of Goods Transported by Roads and Rail	-0.03
	(0.02)
Personal Computers	0.29**
	(0.07)
Bandwidth	0.11**
	(0.03)
Servers	0.08*
	(0.03)
Human Capital	0.70**
	(0.31)
R^2	0.9072
N	65

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. *Significant at 10% level. All variables are in logs.

The financial sector plays a pivotal role in development and trade. It has been argued that the impetus behind the industrial revolution in Europe was due to the amount of investment capital available to firms seeking to increase industrial capacity more so than the number of new inventions developed during that era (see Hicks 1969). The number of listed companies on a domestic stock exchange that does not include investment companies, mutual funds, or other collective investment vehicles is a measure of the size of a country's investment capital market. The market value of a listed company's assets is the market share price times the number of shares outstanding. Theoretically the number of listed companies on a domestic stock exchange is equal to the total value of assets that have been capitalized over a long period of time. Conversely, the size of a country's domestic stock exchange can be a financial constraint on development and trade. I estimate an aggregate production function estimation that includes the number of listed companies on a domestic stock exchange. I conducted a *z* test on the ICT only production function estimates and non-ICT related capital estimates that include the number of listed companies on a domestic stock exchange. The results show no significant difference between the ICT variables when comparing the two models.

Table 3h: Country Estimates of Development Equation
(Aggregate Production Function)

Variable:	Estimates
Constant	7.23**
	(0.52)
Listed Companies on a Domestic Stock Exchange	0.05*
	(0.03)
Personal Computers	0.34**
	(0.07)
Bandwidth	0.12**
	(0.03)
Servers	0.07**
	(0.03)
Human Capital	0.12
	(0.28)
R^2	0.9316
N	84

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. *Significant at 10% level. All variables are in logs.

The last set of tests conducted focused on the human capital variable and the impact different measures of human capital have on ICT. I specify the above aggregate production functions to include different measures of human capital to test whether different measures of human capital impact the returns to ICT. This exercise should give us an indication of the role non-ICT related labor has on development and the returns to ICT. First, I estimate the models above using an education index, which measures the weighted sum of adult literacy and gross education enrollments. Second, I estimate the models using a human development index (that is a composite index of life expectancy, quality of life and knowledge). Third, I estimate the models using labor market participation rates which measures all labor (for individuals aged 15 and older who have primary education) used in the production of goods and services and primary education. All of the above variables can be viewed as labor stock variables.

Table 3i: Country Estimates of Development Equation
(Aggregate Production Function with different estimates of the Human Capital Variable)

Variable:	(1) Education Index Estimates	(2) Human Dev. Index Estimates	(3) Labor Market Estimates
Constant	7.01**	7.42**	7.02**
	(0.22)	(0.31)	(0.30)
Personal Computers	0.27**	0.23**	0.32**
	(0.06)	(0.06)	(0.05)
Bandwidth	0.12**	0.10**	0.12**
	(0.03)	(0.03)	(0.03)
Servers	0.07**	0.07**	0.09**
	(0.02)	(0.02)	(0.02)
Human Capital	0.56**	1.00**	-0.11*
	(0.22)	(0.33)	(0.06)
R^2	0.9016	0.9114	0.8989
N	108	108	108

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. *Significant at 10% level. All variables are in logs.

I conducted a z test on the ICT only production function estimates and non-ICT related capital estimates that include the human development index and the labor market participation rate. The results show no significant difference between the ICT variables when comparing the two models. It should be noted there is a significant difference between the effects of the education index and labor market participation rate.

2.3 Trade Specification

The underlying model, that the exchange of goods and services across borders will increase domestic and international welfare, comes from international trade theory. I utilize this model of trade because it is consistent with international trade theory. Frankel, Stein, and Wei (1995) have shown that income enters positively and multiplicatively in the gravity model, which means that trade between two medium sized countries should exceed trade between small and large countries. Put another way, trade between developed and least-developed countries is unlikely. These outcomes in trade flows would also result from the Helpman and Krugman-type (1985) model of monopolistic competition (see Cyrus 2002). Last, and most important, the gravity model of bilateral trade is consistent with general equilibrium trade models. The trade equation is:

$$T_{ijk} = (y_j)^{\beta 1}(N_j)^{\beta 2}(y_k)^{\beta 3}(N_k)^{\beta 4}(D_{jk})^{\beta 5}(P_{jk})^{\beta 6} \qquad (6)$$

where T_{ijk} is the bilateral trade from country *j* to country *k* in industry *i*; y_j and y_k are the per capita GDP of countries *j* and k; N_j and N_k are the populations of countries *j* and *k*; D_{jk} is the geographic distance between countries *j* and *k*; and P_{jk} is the policy distortion between countries *j* and *k* that includes openness, which accounts for tariff and non-tariff barriers. Note that I define T_{ijk} as copyright related industry trade using the UNESCO 2005, appendix V, table B, p.91 and converted this definition into Standard Industry Trade Classification (SITC, rev 3.). I use the resulting SITC codes to aggregate bilateral trade data published by the United Nations 2007. The result is data on bilateral trade T_{ijk} between all countries (*j* and *k)* in the aggregate of core copyright related industries (*i*).

The gravity model of international trade is the basis for the statistical determinants of trade. Thus taking the log linear form of the gravity model gives:

$$\ln(T_{ijk}) = \beta_0 + \beta_1 \ln(Y_j) + \beta_2 \ln(N_j) + \beta_3 \ln(Y_k) + \beta_4 \ln(N_k)$$

$$+ \beta_5 \ln(D_{jk}) + \beta_6 \ln(P_k) \quad (7)$$

Based on the underlying theory the coefficients are interpreted as elasticity (expected signs reported below):

Table 4: Expected Signs of Parameter Estimates of Gravity Model

Variable:	Expected Sign
Constant	$\beta_0 \geq 0$
GDP	$\beta_0 \geq 0$ & $\beta_3 \geq 0$
Population	$B_2 \geq 0$ & $\beta_4 \geq 0$
Distance	$B_5 \leq 0$
Trade Distortion	$\beta_6 \leq 0$

Hypothesis 2: GDP per capita has a positive effect on bilateral trade in the gravity model. In addition, GDP per capita is assumed to be endogenous to the error term.

I use Hypothesis 2 to answer question (2) – "Does a knowledge-based economy present an opportunity for developing countries to bypass traditional and expensive brick & mortar industries that require large startup investments?" Smith et al. (2009) found a positive and significant relationship between investments in ICT and ICT related trade while controlling for intellectual property rights. In addition, Cyrus (2002) suggests that income in the gravity model of bilateral trade is endogenous and recommends using factor accumulation variables (e.g. ICT) as an instrument in the gravity model of bilateral trade to solve the endogeneity issue. In section 2.5, I provide an argument for this recommendation. Robust estimates of income effects on trade are critical to the argument that ICT induced development encourages ICT enabled trade.

2.4 Estimation Problems with the Gravity Model: What's in the Error Term

Silva and Tenreyro (2006) and Siliverstovs and Schumacher (2008) criticized the log-linear transformation used to estimate the gravity model. Silva and Tenreyro (2006) doubted the consistency of the OLS estimators because the log-linear form depends on an unrealistic assumption of the error term. They were the first economists to put forth the idea that the estimated coefficients in the gravity model are biased upward because misspecification of the error term in the model. The consequence of misspecification is uncertainty and not knowing what determines trade patterns (i.e. not knowing what is in the error term of the gravity model of bilateral trade). I contend that a major component of the error term in the trade equation is a measurement of human capital (labor quality), physical capital, natural resources, and behind the border constraints such as domestic policies that stimulate trade. The aforementioned is the basis for the instrumental variable in this paper.

In addition, the capacity to generate cheap electricity will be in the error term of the trade equation and is one of the biggest hurdles for development. For example, a lot of energy is required to power and cool servers. Countries that can tap into cheap coal to produce electricity will be the most likely destination for industries that rely on servers as a key piece of business/technological infrastructure. It should be noted, countries that generate vast amounts of electricity from nuclear and hydroelectric sources will have the ability to compete in server based industries because of the lower cost associated with the two energy producing technologies.

Moreover, the mobility of ICT makes it accessible wherever you can generate electricity. Wireless telecommunications (wireless broadband, cellular, and satellite technology) eliminates the need to lay physical cable, which is expensive to get to remote locations. For example, landlocked countries and/or countries with small coastlines such as Afghanistan, Democratic Republic of Congo, Central African Republic, and Paraguay can benefit from ICT related trade (Afghanistan is not in the study so I will not offer an example of ICT related trade there, however the others can and do). The Democratic Republic of Congo and Central African Republic can benefit from ICT because their economies are based on export of natural resources. The former is a main exporter of colton (a mineral that happens to be most mobile electronic devices) to the west and the latter is a big exporter of agriculture to the north Asian pacific. Both countries' operations can benefit from real time information and data management. In addition, Paraguay supplies 70% of its pharmaceuticals consumption and is a burgeoning exporter of pharmaceuticals.

Furthermore, I contend that traditional barriers, like being a landlocked country, will have a minimal effect on the error term in the trade equation. Only 6.9% of the world lives in landlocked countries and only 11.4% of the area in the world is landlocked. Within the context of international trade transportation costs are assumed to be higher in a landlocked country because they do not have a natural port of entry for shipping commerce via waterways. I would argue that some copyright related industries minimize transportation costs by producing goods that can be exchanged (replicated) on the web without increasing the cost of production and/or the transportation cost associated with getting some copyright related goods to the marketplace. For example, goods such as songs, works of art, recipes, books, pictures/photos, intellectual property (social networking sites), etc.

Finally, the characteristics of some copyright related goods being produced for or by ICT are attractive to developing countries because the sunk cost (startup capital) required as an entrepreneur in copyright related industries is minimal. Additionally, technological innovation will continue to drive down the cost of startup capital associated with ICT related industries. It should be noted startup costs in traditional industries like agriculture and manufacturing continue to increase. Thus the ability to obtain credit and loans to start and support business will be in the error term of bilateral trade.

2.5 Instrumental Variable Specification

In order to estimate the true impact that per capita GDP has on trade, instrumental variables are used for per capita GDP in the gravity model of bilateral trade. The instruments in the first-stage equation are the logs of human capital, personal computers, bandwidth and servers (ICT). Using these variables in the first-stage equation in an applied instrumental variable approach to solving endogeneity of income in the gravity model of bilateral trade is logical when the bilateral flows are copyright related materials. It is clear from Smith et al. (2009) that ICT (copyright related capital) explains a great deal of variation in GDP ($R^2 > .89$). To be a good instrument these factor inputs should be highly correlated with income and uncorrelated with the error term in the gravity regression.

In this study I assume ICT is exogenous to trade for the reason that there is no clear means by which ICT is thought to influence trade except through income via *K/L* ratio and development. Bergstrand (1989) and Deardorff (1984) generalized the H-O theorem by showing that countries tend to export those goods that are intensively abundant in factor endowments. Bergstrand (1989) goes on to offer a theorem by showing in a multi-industry world an increase in a country's endowment of capital (labor) *tends* to increase the output of the relatively capital-intensive (labor-intensive) industry; and that the coefficient for the exporter's per capita income in the gravity model of bilateral trade is a proxy for the exporter's *K/L* ratio and will have a certain *tendency* in the gravity model to be estimated for capital-intensive or labor-intensive industries. This is a generalization of the Rybczynski theorem. The aforementioned lends credibility to a two-stage approach.

A weak inference of the relative factor intensity of the industry can be made using an exporter's per capita income estimates (coefficients) from a gravity model of bilateral trade. These estimated coefficients are representative of endowment levels and returns to *K/L* ratios, which are the driving force behind trade and development (see Bergstrand 1989). *K/L* ratios are expected to be correlated with income and trade in the gravity model. Specifying the gravity model of bilateral trade with *K* and *L* variables (e.g. ICT) will alter the theoretical underpinnings of the model and will likely be redundant given the prospect that *K* and *L* variables are highly correlated with income in the gravity model, thus violating ordinary least squares criteria that the regressors be linear independent of each other. Furthermore, not specifying the gravity model of bilateral trade with *K* and *L* variables will cause income to become endogenous. This necessitates an instrumental variable approach to solving endogeneity of the explanatory variables due to correlation with the error term in the gravity model of bilateral trade. If the exporter is rich and has an abundance of ICT related capital, then she is expected to have a comparative advantage in copyright related trade. Thus the gravity model of bilateral trade in copyright related material using copyright related capital as an IV is expected to yield unbiased estimators.

Recall, the theoretical model used to measure bilateral trade between two countries (i and j) in this study takes the form:

$$F_{ij} = G \text{ x } (M_i \text{ x } Mj) \text{ x } D_{ij} \qquad (8)$$

where F is trade flow, M is the economic mass of each country, D is the distance, and G is a constant term.[4] The constant term in the model often includes variables to account for income level, factor prices, and trade cost (see Bergstrand 1985).[5] In this paper I measure trade in copyright related material:

$$F_{ijk} = G \text{ x } (M_i \text{ x } Mj) \text{ x } D_{ij} \text{ x } (\varepsilon_{ij\,+}\, \varphi_k) \qquad (9)$$

where k is the industry. In this model there are two components of the error terms in this model ($\varepsilon_{ij\,+}\,\varphi_k$). I base this assumption on the paper by Kalirajan and Singh (2007). They assume that 'behind the border constraints' to exports can impact export flows from export country of origin and these constraints are mistakenly considered part of a statistical error term with normal characteristics in most studies. They say this is an unrealistic assumption. Kalirajan and Singh (2007) elaborate on this by focusing on the effect 'behind the border constraints' have on exports and trade openness. They say that trade openness can be directly estimated (modeled) in the gravity model (e.g. a non-tariff barriers variable); however, identifying and measuring 'behind the border constraints' of the export country of origin that impacts the flow of exports can be understood

[4] Hecksher-Ohlin-Vanek provides the theoretical interpretations.

[5] This is a questionable assumption. The constant term is not truly constant across countries and time. In this study I assume the constant term is constant across countries. Moreover, by assuming the constant term is constant across countries, I am assuming prices are equalized across countries. This is an easy assumption to implement using a purchasing power parity index to equalize prices across countries.

(measured) as an 'economic distance' factor as referred by Anderson (1979) and Roemer (1977). Kalirajan and Singh (2007) interpret this as the error term of the standard gravity model having a two component error term that can be decomposed into *u* ('behind the border constraints') and *v* (normal statistical error term). They say most studies that rely on gravity model estimates do not consider the impact a two component error term will have on OLS estimation. Kalirajan and Singh (2007) suggest lack of attention to the two component error term will lead to bias OLS estimation. Kalirajan and Singh (2007) state: "the term *u* represents the difference between potential and actual output in logarithmic values that is a function of the inefficiencies that are within the exporting countries' control." They also assume that *v* captures the influence other variables have on trade flows (e.g. measurement errors that are randomly distributed across observations in the sample, other left-out variables, and the deviation of the selected functional form from the actual relationship whose impact on exports is considered to be, on average, negligible). In this study I define investment in ICT as a behind the border constraint to trade in copyright related material. Specifically, I assume that per capita GDP is endogenous to the error term, thus requiring an instrumental variable approach to correct for endogeneity. I use ICT to instrument per capita GDP based on the findings by Bergstrand (1989), Cyrus (2002), Kalirajan and Singh (2007) Smith et al. (2009).

The first error component in the model is defined as the economic uncertainty (ε_{ij}) associated with bilateral trade and is expected to be correlated with general price movements of the national economy (see Dixit and Pindyck 1994). Economic uncertainty (ε_{ij}) is assumed to be exogenous to trade. The second error component in the model is defined as technical uncertainty (φ_{ik}) associated with endowments of physical capital and human capital. Technical uncertainty (φ_{ik}) is not correlated with general movements in the economy (see Dixit and Pindyck 1994). However, technical uncertainty is correlated with national income and investment in technology (R&D).

Accordingly, (φ_{ik}) embodies the stock of *K* and *L* in a particular industry. This assertion lends itself to instrumenting per capita GDP in the gravity model with country level endowments of *K* and *L* to solve the endogeneity problem ($y_k = \alpha + \varphi_k + \mu$). Theoretically, this technique will partial out the effect physical capital and human capital (in a particular industry) has on the estimated coefficients in the gravity model. Thus the coefficients in the gravity model are no longer affected by income being endogenous. Last, this approach to solving endogeneity introduces another estimation problem. The production function in equation (5) suffers from omitted variable bias. In this study I include a constant term in the estimated development equations that captures the efficient use of non-ICT related technology (α). As a result the error term in the estimated development equation is assumed to be zero ($\mu = 0$).[6] Note: Per capita income in the gravity model is also present to gauge the importance of development rather than mere size (see Cyrus 2002).

> Hypothesis 3: The estimated coefficients will be significant and different from the estimated coefficients that do not use IVs.[7]

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[6] In addition, ICT augments non-ICT related capital and ICT is expected to be positively correlated with non-ICT related capital. This relationship takes the form of added process and organizational efficiencies (see UNCTAD Information Economy Report 2008).

[7] Note: Another way of stating Hypothesis 3 is "projecting ICT onto income and using the projects in the gravity model of bilateral trade will have a positive and significant impact on bilateral trade. This way of

The precise aim of this paper is to investigate ICT induced trade in copyright related goods and services. Hypothesis 3 is related to question (1) in that I specifically want to measure the impact that ICT has on growth and development. Additionally, I want to investigate the role growth and development have on trade using traditional trade theory and the framework outlined in Bergstrand (1989) paper on the gravity model and microeconomics. I utilize Smith et al. (2009) two-stage framework to measure the impact ICT investment has on development and trade based on the underlying assumption a country will export in the relatively capital-intensive (ICT-intensive) industries.[8] Smith et al. (2009) two-stage framework is similar to Cyrus (2002) IV approach to instrumenting exporter's per capita income in the gravity model of bilateral trade. Combining Smith et al. (2009) and Cyrus (2002) two-stage methodology will allow us to measure ICT induced trade.

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stating Hypothesis 3 may clear up any misconception between testing a theoretical prediction as opposed to an econometric method. The latter is not the purpose of Hypothesis 3.

[8] Smith et al. (2009) analyzed the effect copyrights have on economic development and international trade. First, Smith et al. (2009) specified an aggregate production function to estimate the impact ICT (copyright related capital) has on development (income). Copyright capital consisted of personal computers, bandwidth, and servers which transmit copyright related material. Second, they specified a gravity model of international trade to estimate the impact copyright policies, population, income, and distance have on bilateral trade flows. Third, they combines step 1 and 2 into a two-stage approach to estimating the impact ICT has on trade via income. Smith et al. (2009) find copyright policies between countries has a positive effect on bilateral trade. In addition, Smith et al. (2009) find ICT has a positive impact on development in the step 1 and inserting the predicted values for income in step 1 into the gravity model of bilateral trade in step 2 is significant and the coefficient is different from the coefficient that does not use the predicted values for income in step 1.

2.6 Decomposition Analysis:

If developing countries have the same endowments and income shares (returns) to technology[9], will the gap in trade and development decrease as a result of having the same level of endowments and returns to technology – ceterus paribus? Blinder (1973) and Oaxaca (1973) have proposed methods for testing this counterfactual question by decomposing income inequality between groups into differences in observable endowments and differences in the returns to those endowments. In their study of labor markets – Blinder (1973) and Oaxaca (1973) estimate two wage regressions for samples "*m*" and "*n*":

$$\ln(\text{wage}_m) = \alpha_{01} + \alpha_{11}\ln(X_m) + \varepsilon_{m1} \qquad (10)$$

$$\ln(\text{wage}_n) = \alpha_{02} + \alpha_{12}\ln(X_n) + \varepsilon_{n2} \qquad (11)$$

The regression variables include socioeconomic and demographic variables, such as, human capital variables and age. Blinder (1973) and Oaxaca (1973) are interested in comparing these regressions for the purpose of measuring wage discrimination. They suggest a regression comparison of any two variables will equal a measure of market discrimination (equations 10 subtract equation 11):

$$\begin{aligned}\ln(\text{wage}_m) - \ln(\text{wage}_n) &= \alpha_{01} + \alpha_{11}\ln(X_m) - [\alpha_{02} + \alpha_{12}\ln(X_n)] \\ &= \alpha_{11}\ln(X_n) - \alpha_{12}\ln(X_n) + \alpha_{11}\ln(X_m) - \alpha_{11}\ln(X_n) \\ &= (\alpha_{11} - \alpha_{12})\ln(X_n) + \alpha_{11}[\ln(X_m) - \ln(X_n)]\end{aligned}$$

The second term in the equation measures differences in human capital that will explain differences in wages. The first term in the equation measures differences that are unexplained by human capital. Holding these factors constant at X_n makes the first term attributable to differences in the returns to human capital. Blinder (1973) and Oaxaca

[9] Recall I am using a Cobb-Douglas production function and assuming constant returns to scale technology.

(1973) suggested the decomposition method be computed at the sample means "X_m" and "$X_{m.}$" Last, they used ordinary least squares to estimate the coefficients (α_{11} and α_{12}). If the decomposition regressions are specified with a constant term, then the process will be equivalent to analyzing $\ln Y_m - \ln Y_n$ (see Greene 2003).

Blinder (1973) and Oaxaca (1973) decomposition methodology is a well-known tool used in labor economics to parcel out the effect differences in returns to economic characteristics have on wealth creation. Yet, Blinder-Oaxaca decomposition methodology has not been widely used in trade and development economics to parcel out the effect differences in returns to country level endowments have on trade and development. Decomposition analysis can assist in this analysis. For example, decomposition analysis can determine comparative advantages based on economic endowments and returns to those endowments. For example, it can determine the optimal level of ICT investment needed for industry development that result in export trade. Decomposition analysis output can be used to determine the benefit of investing in trade-related industries where the gains from trade are not obvious and resource allocations may be efficient (inefficient) based on comparative advantage.

Applying the Blinder (1973) and Oaxaca (1973) decomposition method to macroeconomic analysis will require a theoretical connection between macroeconomic analysis and microeconomic analysis. I assume that neo-classical economics and general equilibrium theory is the connection between macroeconomics and microeconomics. Both theories assume preferences for consumption (utility curves) are uniform for all agents; utility curves are maximized for all agents, local non-satiation, and aggregate consumption equals aggregate endowments and production. As a result aggregate income equals national income.

In this study I apply Blinder-Oaxaca decomposition methodology to the development equation to separate the contribution of differences in mean levels of observable country characteristics. Studies show the gravity model explains empirically between 40% and 80% of the variation across countries in one-digit SITC trade flows (see Bergstrand 1989). I believe that differences in technology can explain empirically the remaining variation between groups in one-digit SITC trade flows[10]. That is to say – an instrumental variable approach to the gravity model and Blinder-Oaxaca residual difference decomposition can add meaning to the 20% to 60% of the unexplained portion of the gravity model (ε).

The Blinder-Oaxaca residual difference method requires separate estimations for "*m*" developed and "*n*" developing countries. Decomposition analysis starts with:

$$\ln(Y_m) = \alpha_{0m} + \alpha_{1m}\ln(X_m) + \varepsilon_m \qquad (5a)$$

$$\ln(Y_n) = \alpha_{0n} + \alpha_{1n}\ln(X_n) + \varepsilon_n \qquad (5b)$$

where $m \neq n$.

Y is the income for group m; α_m are the parameters of interest; the vector X contains the covariates that determine GDP; and ε is a random error. The gap in development that is due to country level endowments and returns to those endowments can be characterized as:

$$\Phi = Y_n/Y_m = e^{\Sigma\alpha n^*Xn} / e^{\Sigma\alpha m^*Xm} \quad (12)$$

[10] Differences in endowments of technology are assumed to be due to inequalities in education, income, and investment.

The second component in Blinder-Oaxaca decomposition analysis is the endowment effect. This can explain the gap in development that is due to country level differences in factor endowments:

$$\Phi_E = [E(X_n) - E(X_m)]\alpha_m \qquad (13)$$

The first component in the analysis measures the contribution of the differential associated with the estimated coefficients that embody technological efficiencies:

$$\Phi_T = [E(X_m)](\alpha_n - \alpha_m) \qquad (14)$$

Correspondingly, an interaction term can be estimated to capture the fact that differences in endowments and technological efficiencies exist simultaneously between countries where *c* is a constant or dummy variable:

$$\Phi_S = [E(X_n) - E(X_m)](c - \alpha_m) \qquad (15)$$

Based on decomposition analysis, I can calculate the percent of the disparity in development (and trade) between developed and developing countries due to endowments and technological efficiencies. Below is the mathematical derivation of the estimated gap in growth and development (Φ) when taking the partial derivative of Φ with respect to country characteristics (X). This estimation utilizes a log linear regression. Therefore we have to take the exponential of the log to produce a workable value for Φ and the partial of Φ with respect to country characteristic (∂Φ/∂X). The partial can be interpreted as the marginal effect of country characteristic on the estimated Φ:

$$\Phi = Y_n/Y_m = e^{\Sigma\alpha n^*Xn}/\, e^{\Sigma\alpha m^*Xm}$$

$$=> Y_n/Y_m = e^{\Sigma\alpha n^*Xn}/\, e^{\Sigma\alpha m^*Xm}$$

$$=> \partial\Phi/\partial X = [\alpha_n - \alpha_m]^*[\, e^{\Sigma\alpha n^*Xn}/\, e^{\Sigma\alpha m^*Xm}] \qquad (16)$$

Hypothesis 4: The marginal effect of personal computers, internet bandwidth and servers on the estimated gap in per capita GDP is negative ($\partial\Phi/\partial X < 0$).[11]

Hypothesis 4 is fundamentally related to questions (2) and (3). Question (2) probed the relationship between ICT and development. The next step in this paper is to use hypothesis 4 to answer question (3) – "Does investment in ICT stimulate trade in intellectual property for developing countries, specifically, in the area of copyright related goods and services?" I answer this applied research question using a measured "what if" simulation technique first introduced by Blinder (1973) and Oaxaca (1973) who decomposed wages (income) between different socio-economic groups, i.e. decomposition analysis. It can separate the gap (Φ) in development (income) between developed and developing countries into endowment and technological effects that impact development and trade. The measure of change ($\partial\Phi/\partial X$) in Φ can be multiplied by the estimated income coefficient in the gravity model of bilateral trade to project the impact a change in endowments has on trade gap: Γ = the trade gap associated with the marginal change in country characteristics $\Phi^{\wedge} = \beta_i \ln(Y_j) - (\partial\Phi/\partial X)*\beta_i \ln(Y_j)$. In addition, Γ and $\partial\Phi/\partial X$ can be used in cost/benefit analysis to estimate the investment in ICT necessary to be competitive in ICT enabled trade.

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[11] This is from the perspective that increasing the number of personal computers, bandwidth capacity and servers in developing countries to the level of developed countries will decrease the gap in copyright related trade.

2.7 Data

I utilize two cross-section datasets. Both datasets are published by the United Nations (C*ommodity Trade Statistics Database* [online] and *World Bank, World Development Indicators Database*) and have a large sample of countries to estimate the development and trade equations. The development dataset N = 107 countries and the trade dataset N = 9010 bilateral trade flows. The trade dataset is for both the exporting and importing countries. I utilize cross-sectional datasets because: (1) Cross-sectional datasets are consistent with development and trade theory; (2) The number of pooled cross-sectional datasets across time are only available for a limited number of years; and (3) Variation across countries is greater than variation across time.

All data used in this analysis is for the year 2005 except for the trade distortion variables/trade block variables (for year 2000); which makes the distortion variables exogenous with respect to bilateral trade.[12] This analysis indicates the regression results are robust with respect to patterns of bilateral trade, investment (by World Bank Lending Group) and development indicators. I conducted a descriptive, statistical and market analysis of the data (see Appendix B).

[12] I used two variables to measure trade distortion. The first variable is the Kee et al. (2006) openness measure of the uniform tariff equivalent index that is based on the impact of trade policies on the level of welfare in the importing country. The second variable is the Walter G. Park (2005) and Taylor W. Reynolds (2003) index to measure the strength of domestic copyright protection policies. This measure embodies copyright protection coverage, usage, enforcement, and membership to international treaties.

3. Results

This section reports the empirical findings. To test and answer Hypothesis 1 I estimated the coefficients for the following log-linear equation:

$$\ln(Y) = \alpha_0 + \alpha_1 \ln(Computers_j) + \alpha_2 \ln(Bandwidth_j) + \alpha_3 \ln(Servers_j) + \alpha_4 \ln(Human\ Captal_j) \quad (5)$$

The findings show ICT is positively related to economic development. Personal computers contribute 26% of total income; bandwidth share is 13%; servers share is 7%; and the share for human capital is 55%. ICT jointly accounts for 46% of total income. Thus the findings show a country's ICT is positively related to its economic development (see table 5 below).

Table 5: Country Estimates of Development Equation

Variable:	Estimates
Constant	7.43**
	(1.16)
Personal Computers	0.26**
	(0.08)
Bandwidth	0.13**
	(0.03)
Servers	0.07*
	(0.04)
Human Capital	0.55**
	0.22)
R^2	0.898
N	107

Note: Heteroscedasticity-corrected standard errors are in parentheses.
**Significant at 5% level. All variables are in logs.

Next, I estimate the coefficients for the gravity model in log-linear form to test and answer Hypothesis 2 and 3:

$$\ln(T_{ijk}) = \beta_0 + \beta_1 \ln(Y_j) + \beta_2 \ln(N_j) + \beta_3 \ln(Y_k) + \beta_4 \ln(N_k) + \beta_5 \ln(D_{jk}) + \beta_6 \ln(P_k) \quad (7)$$

The findings conform to expectations. The estimates on per capita GDP and population are positive and significant. Hence development and country size have a positive effect on bilateral trade. Additionally, distance and trade distortions between countries are negative and significant (see table 6 below). It should be noted per capita GDP in the gravity model of bilateral trade is endogenous (correlated with the error term); and the other variables in the model are biased.

Table 6: Country Estimates of Trade Equation

Variable:	Estimates
Constant	-57.38**
	(1.11)
GDP_j	2.29**
	(0.04)
GDP_k	1.78**
	(0.05)
$Population_j$	1.45**
	(0.02)
$Population_k$	0.96**
	(0.03)
Distance	-1.74**
	(0.06)
Trade Distortion (Openness)	-0.24**
	(0.09)
TD (Copyright Protection/Harmonization)	-0.22**
	(0.05)
R^2	.556
N	9,010

Note: Heteroscedasticity-corrected standard errors are in parentheses.
**Significant at 5% level. All variables are in logs

Instrumental variables are necessary for unbiased estimates of bilateral trade in the gravity model. Here, I link development and trade using a two-step process to correct for endogeneity of per capita GDP in the gravity model to determine the true effects of income (and the other variables) on trade. To see the connection between ICT and trade I insert the fitted values $\hat{Y}$ from the development equation into the trade equation (7):

$$\ln(T_{ijk}) = \beta_0 + \beta_1 \ln(\hat{Y}_j) + \beta_2 \ln(N_j) + \beta_3 \ln(\hat{Y}_k) + \beta_4 \ln(N_k) + \beta_5 \ln(D_{jk}) + \beta_6 \ln(P_k)$$

The estimates using the fitted values are positive and significant in the gravity model. The findings support Hypothesis 3 that instrumenting per capita GDP in the gravity model of bilateral trade using ICT has a positive and significant impact on bilateral trade in copyright related industries. Furthermore, the results show that the fitted values have an effect on the other variables in the gravity model; as a result, they have larger effect on bilateral trade than the actual values of per capita GDP in the model. In addition, the estimates of $\hat{Y}$ terms are larger in magnitude and significantly different than the estimates on the actual Y terms (see table 7 below).

Table 7: Country Estimates of Trade Equation
(Instrumental Variable Estimates)

Variable:	Estimates
Constant	-64.39**
	(1.06)
$\hat{Y}_j$	3.01**
	(0.04)
$\hat{Y}_k$	1.94**
	(0.02)
$Population_j$	1.60**
	(0.02)
$Population_k$	1.02**
	(0.03)
Distance	-1.85**
	(0.06)
Trade Distortion (Openness)	-.230**
	(0.09)
TD (Copyright Protection/Harmonization)	-.150**
	(0.05)
R^2	0.583
n	9,010

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. All variables are in logs. y_j *and* y_k are measured as fitted values from equation 7.

Estimating unbiased coefficients is essentially what Smith et al. (2009) accomplished using a two-step approach to estimating the impact ICT has on ICT related trade; and this analysis mirrors Smith et al. (2009) methodology. Although, I depart from Smith et al. (2009) at this point and implement decomposition analysis to show the impact ICT has on development and trade.

3.1 Three Diagnostic Tests: Credibility of the instrumental variable approach

Three diagnostic tests are performed to establish credibility in the instrumental variable methodology used in this study. The first test is a test of instruments relevance. I use Smith et al. (2009) findings to show the strong relationship ICT has on development and trade. The R^2 in the Smith et al. development model is .89. In addition, a diagnostic F-test for the joint significance of the instrumental variables is Prob > F = 0.000 [see Nelson and Startz (1990); Staiger and Stock (1997) and Bound et al. (1995)]. The second test used to establish credibility is a test of instrument exogeneity using an overidentification test. The first step in the overidentification test is to ensure the number of instruments in the model outnumbers the number of assumed endogenous variables (see Wooldridge 2002).

The next step is to test whether the instruments are exogenous variables. I use the Sargan overidentification test to test the aforementioned and the results indicate the instrumental variables used in the analysis are endogenous to the error term [N^*R^2 = 390.13 and $\chi^2(3) = 0.000$)]. This suggests ICT are not good instruments for income in the gravity model of bilateral trade and are correlated with the error term in the model. Given this result, I experimented with reducing the number of IVs from 4 IVs to 2 IVs to determine which proposed IV is the most troublesome in terms of causing rejection of the overidentification. I found reducing the number of IVs did not help pass the Sargan overidentification test [$N^*R^2 = 9.91$ and $\chi^2(1) = 0.005$)]. The only viable instrument according to the Sargan test is the human capital ICT variable. It is the only ICT variable that reported an insigifiance t-statistic and an $R^2 = 0.000$ and a passable Sargan test statistic [$N^*R^2 = 0$ and $\chi^2(0) = 0.000$)]. This is unfortunate because a Sargan overidentification test cannot be computed when the IV regression is exactly identified (see Appendix B).

The third test used to determine the credibility of ICT as instruments in the model is a Durbin-Wu-Hausman test (DWH) for the single endogenous regressor. The result from the test suggests that instrumenting income with ICT is a preferred estimator despite being endogenous. The |DWH| > 1.96 for $\hat{Y}_j$ and $\hat{Y}_k$. Thus suggesting income is endogenous and the need to use instruments. Two out of three tests support the use of ICT in the gravity model of bilateral trade in copyright related material; however I cannot definitively conclude that ICT is a good instrument because the Sargan test shows it is endogenous to the error term in the gravity model. The incongruity between the Sargan test and DWH test suggest that the instruments are bad in the sense they are correlated with the error term in the second stage while the IV results are different from the OLS results in the first stage.

The results give credibility to correcting income endogeneity in the gravity model of bilateral trade using instrumental variables. Correspondingly, estimating unbiased coefficients is a necessary step in the Blinder-Oaxaca decomposition analysis.

The decomposition method requires separate estimation of developed and developing equations. The results for the developed country equation shows ICT contributes positively to economic development (see table 8 below). It should be noted that Human Capital and Personal Computers lose some significance in this model.[13]

[13] The change in coefficient and loss of significance suggests personal computers played less of a role in continued development for developed countries. Note: The personal computer variable is significant at the 10% level. Conversely, the human capital variable does not play a significant role in continued development for developed countries. This may be due to economic liberalization and the mobility of educated labor across developed countries.

Table 8: Developed Country Estimates of Development Equation 5a

Variable:	Estimates
Constant	8.22**
	(.421)
Personal Computers	.15*
	(.099)
Bandwidth	.098**
	(.048)
Servers	.037
--------	(.027)
Human Capital	.164
	(.924)
R^2	.567
N	32

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. *Significant at 10% level. All variables are in logs.

The results for the developing country equation show ICT contributes positively to economic development (see table 9 below).

Table 9: Developing Country Estimates of Development Equation 5b

Variable:	Estimates
Constant	7.02**
	(.243)
Personal Computers	.283**
	(.063)
Bandwidth	.081**
	(.036)
Servers	.083**
	(.030)
Human Capital	.519**
	(.226)
R^2	.809
N	75

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. All variables are in logs.

Because of the population, size of economy, number of educated workers, internet and cellular access, and volume of trade in agricultural and technology related industries I repartition the dataset by adding Brazil, China, and India to the developed country dataset. Note: Brazil is technically a middle income country (see Appendix B); and China and India represent the two largest internet markets (ICT markets) in the world. All three countries established ICT-related trade industries based on comparative advantage. Therefore, I estimate a second set of developed and developing country equations to account for Brazil, China, and India being recoded as developed countries.

The results for developed countries show ICT contributes positively to economic development (see table 10 below). It should be noted servers are not a significant factor for economic development in developed countries.

Table 10: Developed Country Estimates of Development Equation 5a
with Brazil, China, and India

Variable:	Estimates
Constant	7.68**
	(.483)
Personal Computers	.327**
	(.079)
Bandwidth	.084*
	(.046)
Servers	-.005
	(.483)
Human Capital	1.17
	(.666)
R^2	.834
n	35

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level and *Significant at the 10% level. All variables are in logs.

The results for developing countries shows ICT contributes positively to economic development (see table 11 below).

Table 11: Developing Country Estimates of Development Equation 5b without Brazil, China, and India

Variable:	Estimates
Constant	7.00**
	(.313)
Personal Computers	.282**
	(.072)
Bandwidth	.076**
	(.034)
Servers	.095**
	(.034)
Human Capital	.495**
	(.252)
R^2	.809
n	72

Note: Heteroscedasticity-corrected standard errors are in parentheses. **Significant at 5% level. All variables are in logs.

It should be noted all ICT variables are significant at .010 except for servers in developed countries. The magnitude and lack of significance of servers suggest it plays a less significant role in development in upper-income countries. This scenario is more plausible than a scenario where human capital plays an insignificant role in development in developed countries. Therefore, I use the development model that includes Brazil, China, and India as developed nations in the decomposition analysis.

3.2 Significant Difference between Developed and Developing Equations

I conducted two F-test to determine if the estimated coefficients in the three development equations are significantly different from each other. I conducted a Chow test to determine if the separate developed and developing equations are significantly different than the aggregate development equation. The result of this test shows there is a structural difference between the aggregate development equation and the two sub-equations (developed and developing equations) at a Prob > F = 0.100. The second test conducted is a Chow predictive test that is equivalent to extending the restricted model to the shorter sub-equations and basing the test on the predicted errors of the sub-equations. The result of this test shows there is a significant difference between the developed and developing equations at a Prob > F = 0.050.

3.3 Blinder-Oaxaca (1973) Decomposition Analysis: Outcome

Based on Blinder-Oaxaca's (1973) 2-component decomposition method, roughly 58.44 percent of the gap in income can be explained by the endowment effect i.e. differences in country level endowments of ICT, with 41.56 percent of the total residual due to relative income shares (returns) to technology (see table 12 below). The total gap in income between developed and developing countries is the difference between (a) – (c) in table 14. The explained portion of the gap in income is (a) – (b),[14] which measures the endowment effect and identifies the gap in income that is attributed to differences in the level of endowments. The unexplained portion of the gap in income is the difference between (b) – (c).[15] This measures the technology effect and identifies the gap in income that is attributed to differences in returns to ICT. Put another way, it measures the efficient use of inputs. The term "unexplained" fits with theories of innovation and R&D, which suggest growth in output that cannot be explained by growth in inputs and is left to our ignorance and/or is unexplained. Nonetheless a higher return on the initial level of inputs (endowments) is evident. In this study I interpret the unexplained portion of the income gap as differences in relative income shares (returns) to ICT. Note: in

[14] $\Phi_E = [E(X_n) - E(X_m)]\alpha_m$

[15] $\Phi_T = [E(X_m)](\alpha_n - \alpha_m)$

equilibrium, relative income shares are equal to factor input prices. A significant difference in factor input prices gives the exporter in this model a comparative advantage.

Table 12

Decomposition Analysis
(Residual Difference)

Dependent Variable = ln(GDP)				Total	Explained	Unexplained
	N	Mean of Dep		(a) - (c)	(a) - (b)	(b) - (c)
Developed estimated	35	10.116	(a)			
Equal Technology value of Developing*	72	8.713	(b)	1.751	1.403	.348
Developing estimated	72	8.365	(c)			
* Multiplication of Developed coefficient estimates and Developing characteristics						

To derive a practical interpretation of the residual difference created by disparities in technology and endowments I use the residual difference equation to compute the gap in income attributed to technology and endowments associated with developed and developing countries (see equation 17 below):

$$RD = \exp[(lnY^{developing\ with\ equal\ \mathrm{technology}}) - (\ln Y^{developing}) - 1] = 41.56\% \qquad (17)$$

I find a positive and significant difference (sig = .010) between the total gap in development $[((a) - (c))/\sigma_y^{developed} = 2.488]$ and the explained gap in development $[((a) - (b))/ \sigma_y^{developed} = 3.106]$ which indicates developing economies will decrease the gap in income between developed and developing countries by 41.56 percent if they have the same return on ICT investment as developed countries.[16] Put another way, I do not find a

[16] It should be noted the developing economies parameters could equally be used as reference weights giving: $RD = \exp[(lnY^{developed\ with\ developing\ \mathrm{technology}}) - (\ln Y^{developed}) - 1] = 26.50\%$. Henceforth, there are two ways of implementing the Blinder- Oaxaca (1973) decomposition analysis. Since the perfectly competitive return on endowments market equilibrium structure is not known, choice of the reference group is arbitrary (See van de Walle and Gunwardena 2000). This indicates that if developing economies had the same level of per capita endowments as developed economies their respective rate of return on investment in ICT

significant difference between the unexplained gap in development $[((b) - (c))/\sigma_y^{developing} = 0.386]$ which means developing countries would increase their rate of development associated with ICT by 58.4 percent if they had the same level of investment in ICT as developed countries. The above finding coupled with equation 16 indicates developing countries should invest in ICT to reduce the gap in ICT enabled development and trade because 58.4 percent of the investment cost in ICT can be returned to developing countries in the form of gains from trade that is linked to being a developed economy according to the gravity model of bilateral trade. The estimated effect per capita income (development) has on bilateral trade is robust. Equation 16 indicates the gap in income (Φ) will decrease by (-.227) percentage points with a 1 percentage point increase in the level of endowments in ICT (see equation 16 below).

$$\partial\Phi/\partial X = [\alpha_n - \alpha_m]*[e^{\Sigma\beta n*Xn}/ e^{\Sigma\beta m*Xm}] \qquad (16)$$

$$=> [-1.308]*[.174] = -.227$$

Recall the projected impact a change in endowments has on trade gap Γ = the trade gap associated with the marginal change in per capita income (development) $\Phi^{\wedge} = \beta_i \ln(Y_j) - (\partial\Phi/\partial X)*\beta_i \ln(Y_j)$.

It should be noted the Blinder-Oaxaca decomposition analysis is a simple method of decomposition that ignores any possible contribution of the differences in development due to unobserved random error. These limitations are noted by Juhn, Murphy, and Pierce (1993). In addition, I indicate possible issue with the error term, trade and development below.

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would differ by 15 percentage points (41.5% – 26.5%). Thus developing economies would increase their rate of development associated with CRI by 73.5 percent if they had the same level of endowments in ICT. In addition, equation (16) is unchanged.

3.4 Theoretical and Methodological Reasons for the Gap in Trade and Development

I attempt to measure the gap in trade and development by looking at how different levels of investment in ICT effect the aforementioned – a computational exercise. Now I offer some theoretical and methodological reasons for the gap in trade and development.

Theory of the Firm: Dunning 1976 observed that incomplete markets force firms to internalize (hold) knowledge-based assets within their firms thus establishing affiliates abroad. This theory suggests that location and ownership advantages outweigh trade advantages and FDI will be a means to mitigate risk associated with marketing knowledge-based assets abroad. In this case, FDI is a substitute for import trade but export trade. Spillovers from FDI will impact the foreign markets productivity. Income will be impacted by FDI in the form of an increased *K/L* ratio.

Trade Theory: New developments in trade theory (in particular, New Trade Theory) puts forward the idea that firms choose to access foreign markets based on their competitive advantage and cost structures. Helpman et al. (2003) discovers three facets of the firm that will impact trade and development. They find that the least productive firms only serve domestic markets, and the more productive firms serve domestic and foreign markets through various means of exchange (exporter, establish subsidiaries abroad, or through licensing); and only the most productive firms engage in FDI as measured by cost structure and returns to technology at the firm level and capture by aggregate *K/L* ratios at the country level.[5] Thus FDI will have a positive effect on development though increasing exporter K/L ratio, and will be a substitute for in-country imports. In this case the effect FDI has on bilateral trade is mixed.

Perhaps the gap in trade and development can be attributed to repressed financial opportunities in developing countries. If the returns to factor inputs are the same across borders then what explains the disparity in investment in ICT. The stark reality for developing countries is production capabilities are a function of the availability of financing and credit to cover fixed set-up costs for new firms.

Bergstrand (1989) represents the firm's technology as having a fixed set-up cost (α) that is part of the constant input requirements equation to produce a unit of output *X*:

$$L = \alpha + \beta_L X$$

$$K = \alpha + \beta_K X$$

If national price levels equalize, this set-up cost is the same in developed and developing countries. If national prices do not equalize between countries, financial markets will not equalize across countries. Another way to look at it is if price levels do not equalize in currency and financial markets the result is differentiated products that sell in markets where their return is the highest. This presents an opportunity for multinational enterprises to take advantage of varying prices across countries.

Bergstrand's (1985) survey of these issues finds large persistent deviations of national price levels from purchasing power parity (PPP), and equality of price level across countries (PPP) will not turn out to be the norm, even in the long run. He also finds it difficult to match "the most" disaggregated manufactured commodities for which U.S. and foreign prices can be matched. This suggests relative price behavior will make them differentiated products rather than near-perfect substitutes. Economists before Bergstrand (1985) find that commodity arbitrage did occur; when it did occur it was neither significant nor perfect for every commodity group, if for any of the commodity groups (see Isard 1977, Richardson 1978, Kravis and Lipsey 1984).

Lipsey (1984) suggests that factor price equalization will not be the norm in the long run. This goes against the Heckscher-Olin model, which stresses that provided certain conditions are met, countries will specialize in the production of goods where they are comparatively well endowed and will export these in exchange for others goods where they are comparatively less endowed and, after repetitive exchange, factor prices will equalize. This is a major theoretical underpinning of international trade. However, in the case where prices do not equalize, similar goods become dissimilar thus presenting an opportunity for arbitrage that can take the form of local investment opportunities (in startup companies) competing with FDI and multinational enterprises. For more discussion on factor price equalization and arbitrage see Nurkse (1933), Ohlin (1933) Iversen (1935), Samuelson (1948), and Mundell (1957). It should be noted decomposition analysis can be used to account for the role direct and foreign direct investment play in the formation of capital and labor in copyright related industries. Recall, imbedded in the gravity model are the fixed costs associated with factor inputs K and L.

Neo Classical Theory: The premise that the exchange of goods and services across borders will increase domestic and international welfare is central to trade policy. It is shown using the *Allocation Mechanisms Theory* that for all countries trade and development can be characterized as a social choice function F that represents a political economic environment. F is Pareto efficient if for every net trade and investment (allocation z) which is an element of $F(\theta)$ [e.g. $z \in F(\theta)$] there does not exist a θ' such that $F(\theta')$ is preferred to $F(\theta)$ [$F(\theta') \geq F(\theta)$], where θ equals country preferences u and endowments ω. Put another way, for all possible allocations of net trades (ranging from autarky to free trade) there does not exist any feasible outcome of net trades z such that $u(\omega + z') \geq u(\omega + z)$ for all countries (and with strict inequality for at least one country). This suggests that a rational trade and development policy will be the outcome because the social choice function F is individually rational for each country if a trade (i.e. exchange) takes place [$u(\omega + z) \geq u(\omega)$]. Despite neo-classical economic theory I find a disparity in trade and development that is defined by income differences between countries.

Measurement and Methodology: the Blinder-Oaxaca (1973) decomposition method estimates a -.227 percent point change in the income gap that can be attributed to the difference in ICT between developed and developing countries. I estimate the gap in income using a Dummy Variable method. This method estimates gap in income based on being a developing country versus a developed country. Using the dummy variable method I estimate a -36.3 percent difference in income based on being categorized as a developing country (see table 13 below).

Table 13: Country Estimates of Income Equation
with Developing Country Dummy Variable

Variable:	Estimates
Constant	7.53**
	(.261)
Personal Computers	.264**
	(.057)
Bandwidth	.090**
	(.027)
Servers	.059**
	(.021)
Human Capital	.626**
	(.191)
Developing Country	-.363**
	(.115)
R^2	.910
n	107

Note: Heteroscedasticity-corrected standard errors are in parentheses.
**Significant at 5% level. All variables are in logs.

This suggests that the decomposition method may overestimate the returns to ICT. It should be noted the Blinder-Oaxaca (1973) decomposition method decomposes endowments and technology at the mean, and the dummy variable method estimates the difference in being characterized as a developing country based on income at the mean. It is evident that the total gap in income estimated by the two methods differs substantially; hence methodological error and measurement error should be taken into account when applying disparity analysis to trade and development data.

Concluding Remarks

I conclude that investment in human capital and ICT can reduce the gap in growth and development between developed and developing countries by 58.4 percent. Additionally, evaluation of the standard errors in the decomposition analysis points to, on average, developed countries do not have a comparative advantage in trade based on returns to ICT (factor prices). The results suggest investment in ICT is a competitive means for growth and development. The policy implication are twofold: (1) human capital and ICT investment is necessary for continued growth and development; and (2) ICT investment is a significant differentiator between high-income and lower to middle income countries.[6] The United Nations Conference on Trade and Development (UNCTAD) is advocating that countries like the Democratic Republic of Congo, Rwanda, and other developing countries with little ICT related trade, invest in knowledge-based assets to develop their economies (see UNCTAD 2010: http://www.unctad.org/Templates/StartPage.asp?intItemID=2068). UNCTAD (and the ITU) believes knowledge-based economies will lead to growth and development.

Appendix A Data and Sources

All data used in this analysis is for the year 2005, except for the trade distortion variables for year 2000.

The measure of development (y) is GDP per capita for each country in current purchasing-power-parity (PPP) dollars.

The first measure of human capital (l) is an education index for 2004/2005 measured as a weighted sum of adult literacy and gross educational enrollments. This index takes values from 0 to 100 and is published by the World Bank in the *World Development Indicators*. The second measure of human capital (l) is a human development index for 2005 (that is a composite index of life expectancy, quality of life and knowledge) and is published by the World Bank in the *World Development Indicators*. The third measure of human capital (l) is a labor market participation rate for 2005, which measures all labor (for individuals age 15 and old who have primary education) used in the production of goods and services and is published by the World Bank in the *World Development Indicators*. The measure of capital includes three components. I scale these measures by population to calculate per capita units. The first measure (k_1) is the number of personal computers per capita in each country. The second measure (k_2) is internet bandwidth in bits per capita for each country. The third measure (k_3) is the number of secure internet servers per capita for each country. All of the k measures are published by the World Bank in the *World Development indicators*. The measure (T) is bilateral trade in core copyright industries in current U.S. dollars, published by the United Nations in the Comtrade dataset. I convert this data from U.S. dollars to PPP dollars to establish comparability with other measures. I make this adjustment using PPP conversion factor published by the World Bank in the *World Development indicators*. The term *N* is population for each country and is published by the World Bank in the *World Development indicators*. The term *D* is geographic distance between the largest city in the exporting country and the largest city in the importing country and is published in the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). The *O* is the policy distortions terms and is published by Kee et al. (2006). The term *C* is an index measure of copyright protection constructed by Park and Taylor. Last is the term (categorization) *Developing Country* published by the World Bank, July 2009.

The net value added variable is the value added to an economy by industry as a percent of GDP. This variable is an index of net value added to an economy by a particular industry divided by GDP. The index is published by the World Bank in the *World Development indicators.*

The arable land, tractors per 100 sq. km of arable land, livestock production, the percentage of paved roads, the volume of goods transported by roads and rail measured in million metric tons times kilometers traveled, and the number of domestic companies listed on a country's stock exchange excluding investment firms, and mutual funds are measures published by the World Bank in the *World Development indicators.* The energy production and energy consumption measures are composite variables that include petroleum, natural gas, coal, combustible renewables, and primary electricity all measured in kilotons of oil equivalent. The index is published by the World Bank in the *World Development indicators.*

Appendix B Descriptive Statistics and Correlations (see PowerPoint attachment/companion)

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[1] In this study knowledge-based economies exchange intellectual property as the primary assets. Intellectual Property (IP) are ideas that can be codified into private property. "These ideas may take the form of *copyrights* where material such as books or music can be copied only with permission from a copyright owner, who can charge for this; or patents, where processes or product designs can only be used with permission from the patentee, who can charge a license fee. Such property rights originally rest with authors or inventors, or their employers, but can be bought or sold," (Definition is from John Black Oxford Dictionary of Economics). In general, knowledge-based economies are characterized by 1) capital mobility and 2) economies of scale. Carr, Markusen, and Maskus (2001) provide an active description of a knowledge-based economy:

1. Services of knowledge-based and knowledge generating activities, such as R&D, can be geographically separated from production and supplied to production facilities at low cost (which creates vertical fragmentation).
2. These knowledge-intensive activities are skilled-labor-intensive relative to production (which creates vertical fragmentation).
3. In addition, knowledge-based services have a (partial) joint-input characteristic, in that they can be utilized simultaneously by multiple production facilities (which create firm level scale economies and motivate horizontal investment that replicates the same products or services in different locations).

[2] Ethan Kapstein (2000) characterizes the new economy as follows: "Since the early 1990s, American economic performance has been phenomenal. The duration and strength of the nation's growth rates have exceeded the expectations of analysts both within and outside the United States government, and private sector investment; especially in

computers and information and communications technology (ICT), has boosted the output of its manufacturing workers. This combination of high growth, low inflation, full employment, and technological innovation and adaption has created what many observers call a new economy".

[3] In this paper ICT is an endowment based on the definition of factor endowments provided by John Black in the Oxford Dictionary of Economics: "Factor endowments [are] a country's stock of factors of production. The term endowment is rather misleading. So far as land is concerned, its area and location, and the minerals under it are given by nature; but the quality of the land can be improved by drainage or irrigation, and damaged by deforestation and erosion, and known mineral resources reflected effort put into investigating them. The labor force at any time is given by history, but in the long run can be affected by health and social measures which affect both and death rates, and policies towards immigration and emigration. The capital stock, again, is predetermined at any moment by past investment, but its growth is affected by savings and by policy on international capital movements. Human capital can be affected by education and training," (John Black 1997). The paper closely follows the definition provided by Black (1997), Specifically, the idea that a country's capital stock is predetermined at any moment by past investment, growth is affected by policies on international capital movements, and the assertion that factors of production are the same as factor endowments. According to Black (1997): "Factor[s] of production [are] any resource used in the production of goods or services. Factors of production can be broadly classified into three into three main groups: labor, or human services; capital, or man-made means of production; and land, or natural resources. Each of these broad

groups of factors of production can be subdivided in various ways, for example labor with various amounts of human capital, or land with various mineral contents," (John Black 1997). In conclusion, the definitions for factor endowments and factors of production provide the working definition for endowments in this paper. I see endowments of ICT as belonging to the "capital, or man-made means of production" group classification. In this classification "man-made means of production" insinuates that factors of production can be endogenous. Thus I assume in the paper that ICT is an endogenous endowment like a mineral deposit that cannot be taped without investment income. I will refer to ICT endowments as investments. This will have two impacts on the paper: 1) it will clear up the confusion about endowments being strictly exogenous, and 2) it will be easier to talk about ICT as investments when compared to other capital variables that will be included in the model to control for non-ICT related capital. Last, the definition provided by the Oxford Dictionary of Economics says nothing about endogenous or exogenous endowments. In addition, Varian and Mas-Colell et al. do not provide a working definition of endowments besides mentioning that they are goods used in production.

[4] Alan Blinder and Ronald Oaxaca are best known for developing one of the most important methods used in the field of labor economics to study wage discrimination based on education, sex, and race known as the wage gap decomposition, (see Oaxaca's 1973 article "Male-Female Wage Differentials in Urban Labor Markets). "The wage gap decomposition provides a means for identifying residual differences between observed and predicted wages that are not accounted for by characteristics associated with productivity, such as education and skill, and can thus be attributed to labor market

discrimination and other omitted variables. The seminal method has since been refined and elaborated upon to add other elements of analysis, such as the use of alternative wage structures as reference points for comparison; selectivity bias; comparative analysis across countries and time; the explanation of penalties associated with motherhood; and analysis of discrimination across the income distribution rather than using means," (http://www.encyclopedia.com/doc/1G2-3045301787.html)

[5] Berger and Hannan (1998) model the problem as an efficient frontier (efficiency measure) that achieves a minimum technological cost, rather than cost minimization. They seek to explain within-sector firm productivity and restrict their study to inter-industries trade where they compare "best practices" as a measure of efficient use of technology.

[6] The intent of the paper is to present an analytical framework that can weigh investment opportunities in ICT for development and trade. I see the ICT investment decision being broken into two parts. The first part determines the strength of comparative advantage in a particular industry. And the second part measuring the return of investing in ICT relative to the trade it will stimulate in intellectual property related industries. I envision policy makers using these pieces of information as an initial determination whether or not they should look into investing in ICT-related trade. The cost of investing in ICT is straightforward; most ICT-related goods have an off- the-shelf price. On the other hand, the return to ICT-related trade has to be projected, which comes with a lot of uncertainty. Blinder/Oaxaca decomposition analysis gives us an opportunity to simulate changes in development and trade based on investments in ICT. The weakness of this approach is the accuracy of the measured change and the projected returns to investment in ICT.

Nonetheless, I would contend investment in ICT comes at a cheaper cost than investment in education and healthcare. A good case study of this point is what we see happening in developing countries today and over the past decade in the area of technology, education and healthcare. The cost of education and healthcare has more than doubled in the US over the past decade while the cost of ICT fell over the past decade. In citing these patterns I would also say investment in ICT will drive down the cost of education and healthcare (e.g. the pupil marginal cost of online courses and cost savings associated with paperless access to online medical records). In addition, human capital is considered an ICT investment in this paper. The impact human capital has on income is included in the decomposition analysis; hence human capital is a big part of the argument I am making (it has the largest estimated impact on income in the estimated development equation independent of the measuring error normally associated with measurements of human capital). Moreover, I see ICT and human capital as complements and on some level endogenous to each other. If a country can import the technology necessary for an ICT-related economy then it can bypass the beginning phases of investing in a cadre and/or critical mass of engineers, investing in speculative R&D, and the cost of bringing new technologies to the marketplace. This can be very expensive. Instead, developing countries can focus on using technology for commerce. The amount of education required to use technology is less than the amount of education necessary to create technology. This implies investment in ICT may be a cost effective policy (means) to development.