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Internet Use and Economic Development: Evidence and Policy Implications

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by

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Abstract

This dissertation explores how Internet use impacts four different measures of economic development using several econometric techniques on multi-country panel data. The economic development outcomes investigated are: per capita GDP, per capita export revenues, per capita market capitalization, and societal well-being as measured by the United Nations Human Development Index (HDI). Data from the World Bank, the International Telecommunication Union, and the United Nations –covering 202 countries over the period 1996 to 2007– are combined to allow for empirical investigation using dynamic panel data and finite mixture model estimation techniques on the total sample and subsamples stratified by country income level. The results suggest that countries benefit differently from increasing Internet use and the magnitude of the effect depends on the income level of the country. In low-income countries, additional Internet use has a significant positive effect on per capita GDP and overall welfare, as measured by the HDI. Increasing Internet use has a significant positive effect on all four measures of economic development in countries that have achieved middle-income status. Since Internet use affects economic development outcomes differently depending on the income level of the country, the policy recommendations must also vary according to the country's income level.

1 Introduction

This dissertation investigates the effects of Internet use on economic development by using panel data and panel data estimation methods on four different economic development outcomes from 202 countries over an eleven-year period spanning 1996 to 2007. The primary hypothesis under investigation is that increasing Internet use positively affects the following development outcomes: GDP, exports, size of domestic equity markets, and overall welfare as measured by the United Nations Human Development Index (HDI). However, Internet use affects economies differently depending on the income level of the country. The effect is likely to be higher in middle-income countries than in low or high income countries. This may be due, in part, to the lack of widespread Internet use in low-income countries and the decreasing marginal product of Internet use in developed countries that have near universal adoption.

This dissertation therefore stratifies countries according to income class as defined by the World Bank[1] in order to create the four samples of interest: the full sample of all countries, and samples for each income category: low, middle, and high. The effectiveness of Internet use is tested on each sample and the results are compared to explore the effects of additional Internet use at different developmental stages. The econometric investigation will use a production function framework with Internet use as an additional input.

[1]See Appendix A for a complete list of countries organized by income levels.

The emergence and expansion of the global network of computing resources known as the Internet may be as significant a development in human history as the creation of the printing press. Widespread and consistent access to the collective computing resources and Internet enabled devices of the world has forever changed how we interact, conduct business, learn and govern ourselves. The economic consequences of the Internet are remarkable. Internet use makes markets more efficient by reducing transaction and search costs and by increasing access to information on goods and services available within domestic markets and throughout the world. Access to information inspires innovation, eases the adoption of new technologies, and increases productivity.

The news reports are filled with stories of how technological solutions are changing the way business is conducted in the developing world. From farmers in Kenya using cell phones for Internet access connecting with insurance agents to protect their crops (DAWN Media Group 2009), to Chinese Internet centers for remote villages (Fong 2009), to Indian fisherman using cell phones to locate markets with the greatest demands for their products (Jensen 2007), the evidence of the effects of Information and Communication Technologies (ICT) on economic growth abounds and the possibilities seem endless[2].

As individuals and organizations in both the private and public sectors of developing economies increase utilization of the Internet, this stimulates opportunities for the creation of new products and services. Ultimately, expanding access to information provides for market transformation where new markets may emerge and existing markets can evolve, growing in size, scope and interaction with markets in other countries or regions. The potential for transformation of governance through information use

[2]Aker and Mbiti (2010) provide an excellent overview of the impact of cell phones on economic development in Africa.

provided by Internet access is enormous, a prospect that clearly worries autocratic rulers who immediately restrict Internet access in times of social upheaval as seen during the unrest throughout the Arab world in early 2011.

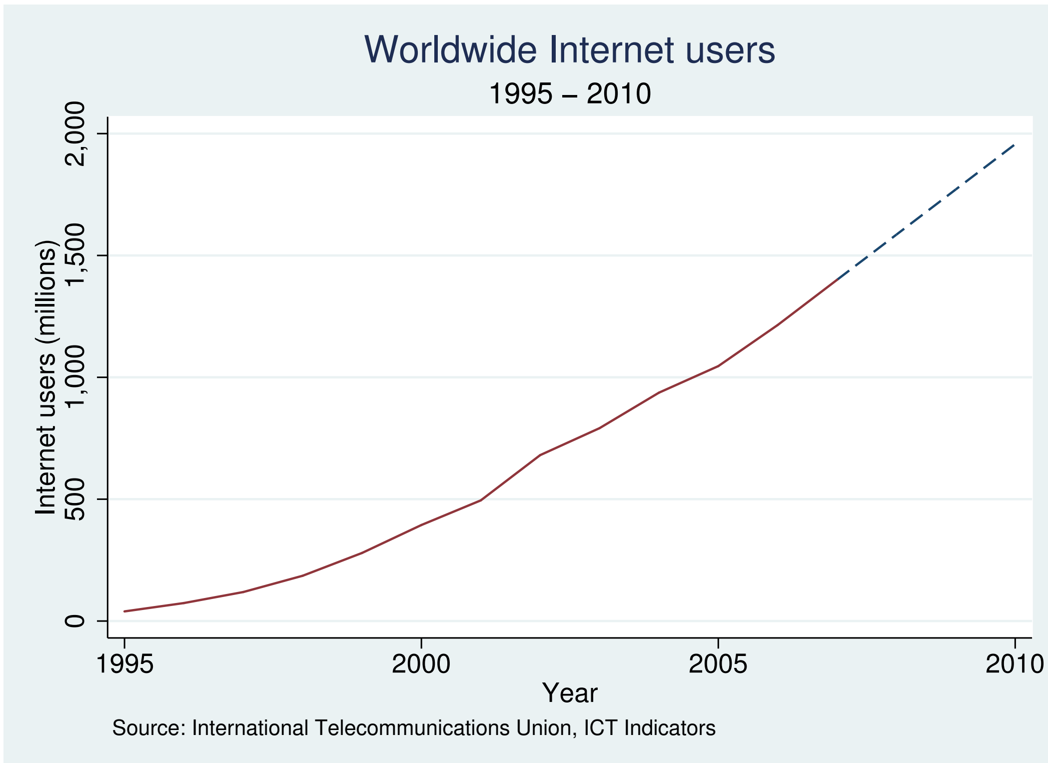

Figure 1: Worldwide Internet users

Over the last 15 years, the Internet has grown and become accessible to users worldwide at an astonishing rate, as depicted in Figure 1. Network-enabled computers have become ubiquitous in households, businesses and educational institutions throughout the developed world. The influence of computers and the Internet can be found in almost every aspect of developed economies. In the industrialized world, Internet connectivity is becoming increasingly regarded by the citizenry as a basic service, similar to electrical power, municipal water and pubic roadways. Access to the Internet is ubiquitous, reliable and, for the most part, inexpensive. Citizens and visitors alike can expect to find access to the Internet with the same regularity as they find electrical power outlets, modern transportation facilities, and sanitation services.

In much of the developing world, Internet access is available only in large population centers, if it is available at all. Connectivity to the global communication networks that facilitate Internet use in less-developed countries (LDCs) is becoming more widely available only as advancements are made to the required electrical power and communication infrastructures. Unfettered connection to the Internet is impossible without widespread availability of electrical and communication resources. Although the Internet may have the potential to increase productivity and human welfare, this potential cannot be cultivated without access to this technology. The ability of the population to afford or access computers or other Internet enabled devices is fundamental for the Internet to have significant positive economic effects.

In LDCs, often the political and social institutions are not stable, nor incomes high enough, to provide the investment necessary to create even the most basic reliable public utilities. Poor, but stable, countries are unable to sustain the required infrastructure to support widespread Internet access. Borrowing from psychologist Abraham Maslow (1943), if we consider an economic hierarchy of needs for a developing country, stable political and social institutions and basic public utilities such as electrical power distribution and education resources are more basic needs, while Internet use is a higher order need. In countries where the population must focus on basic survival due to extreme poverty, missing or failing public health institutions, ongoing violent conflict, or generally unstable political systems, accessing the Internet will not be a priority, if it can be done at all.

The weaker than anticipated results of the "One Laptop Per Child"[3] initiative in LDCs provides some anecdotal evidence of the inability of technological solutions

[3]A program to provide low-cost network connected laptops to children in developing countries. For more information see: http://www.laptop.org/.

to yield reproducible and meaningful outcomes in countries without basic political, social, and economic institutions as well as the necessary infrastructure (Shaikh 2009). Of course, information provided on the Internet is of little use to the illiterate members of a population who cannot gain access to the information. This dissertation provides empirical evidence that increasing access to, and use of, information and knowledge that Internet connectivity provides has significantly positive effects on development outcomes and how the magnitude of this effect differs for economies at different levels of development.

There is limited empirical work on the effects of Internet use on development outcomes in the economic development literature. The few studies on the subject have narrowly focused on either income growth or on the productivity of a particular industry. But, economic development is far broader than simply income growth rate. This dissertation is an attempt to empirically investigate the effects of Internet use on several different development outcomes. Section 2 provides a summary of the literature and highlights the research gap that this dissertation fills. The possible productivity enhancing effects of increases in information dissemination that the Internet provides across the globe, especially in LDCs, has yet to be explored empirically in detail.

In this dissertation I provide a simple theoretical framework within which to analyze the effects of Internet use on economic development. I then apply the model to a panel containing data on a large number of countries at all levels of development. Previous studies on ICT and economic development have been limited to growth effects, but development is more than simply GDP growth. This investigation provides a more comprehensive view of the effects of Internet use on development by expanding the range of effects of development outcomes investigated. Additionally, prior studies tend to use cross-country regression techniques that are incapable of analyzing dynamics. In this investigation, I use panel data and econometric estimators that can account for dynamics and unexplained heterogeneity. I also estimate the models using mixture modeling techniques as robustness tests. Existing studies assume linear responses to the effects of ICT on all countries, or on a specific country. This is not likely to be the case as the ability to use and benefit from Internet use may differ according to the level of development as discussed above. Therefore, I stratify countries into income classes and consider the effects on each class.

Data from a variety of sources including the World Bank, the International Telecommunication Union, and the United Nations covering 202 countries over the period 1996 to 2007 are combined to provide a rich data set for the econometric investigation using dynamic panel estimation techniques. The analysis demonstrates that Internet use has a significant positive and arguably casual effect on several measures of development in countries that have achieved sufficiently high income levels. The development outcomes under consideration in this dissertation are: per capita GDP, per capita export revenues, and per capita equity market capitalization. Per capita GDP is perhaps the most common development outcome measure in the development literature and a thorough investigation of economic development must consider this measure of economic output.

The development and growth literature contains some important investigations on ICT and exports[4]. However, there is very little extension to other development outcomes. This dissertation extends those studies by investigating the relationship of Internet and exports using a model that controls for dynamics. Chapter 5 presents the comparison and evaluation of the results. There is an emerging literature on domestic financial markets and economic development with a focus on raising development financing. This dissertation extends that literature by exploring the effects

[4]For example: Freund and Weinhold (2002), Freund and Weinhold (2004),Clarke and Wallsten (2004), and Clarke (2008).

of Internet use on domestic financial markets. Specifically it investigates the relationship between Internet use and capitalization rates of domestic financial markets – arguably a measure of development of such markets.

In order to investigate how Internet use impacts a broader measure of societal well-being, the United Nations Human Development Index (HDI)[5] is used as an additional measure of economic development. In this study, as in many others, the HDI is considered a proxy for the general well-being of the population within a country. As access to the Internet becomes more readily available in developing countries, front-line health care providers will have access to more information including new methods and best practices for dealing with pressing health issues they experience. Further, Internet use can facilitate educational outcomes measured by literacy rates. These factors are combined in the HDI index, which makes it an interesting proxy for over-all well-being.

The empirical investigation explores the hypothesis by comparing results of estimating a variety of econometric models on each sample. Dynamic panel data and finite mixture model estimation techniques are used in order to account for or control for endogeneity arising from the potential simultaneity problem of jointly determined dependent and explanatory variables. By controlling for the likely endogeneity of the measure of Internet use, a case can be built for the causal effects of Internet use on the economic outcomes.

There are a number of potential mechanisms through which Internet use positively affects economic outcomes. Access to the Internet increases information flow which reduces distances between people, firms and nations which in turn reduces transactions and transportation costs. Technological progress depends on the exchange of

[5]The UN Human Development Index (HDI) is a composite measure of education, literacy, and income published periodically by the United Nations Development Programme.

ideas and information. Granovetter (2005) finds that social networks have strong effects on economic outcomes especially in fostering innovation, and one of the fastest growing forms of Internet communication are websites providing social networking facilities such as Facebook. With increased information availability, provided by access to the Internet, institutions may become more efficient and transparent leading to better governance. Kalathil (2003) builds a strong case that Internet use can increase effective governance and as Acemoglu et al. (2001) have shown, stronger institutions can lead to positive economic outcomes.

Information exchange makes markets more efficient by reducing search and transaction costs which in turn can boost domestic production, increase demand and promote opportunities for trade since it brings buyers and sellers together thus enlarging markets. Internet and other forms of information technology can create new markets industries. Internet availability provides access to educational resources that can lead to additional human capital formation and increased labor productivity. Similarly health information on the Internet is bringing health services to those who may not have had access otherwise. These kinds of effects can stimulate and amplify development outcomes in economies at all levels of development.

Studies highlighting the transformative power of increasing use of the Internet are beginning to appear more frequently in the literature. Parikh et al. (2007) provide a comprehensive overview of the mechanisms by which small rural farmers in India and Central America can utilize ICT in order to reach new markets, learn new techniques through shared experiences and develop more resilient supply chains. Reynolds et al. (2004) demonstrates how more advanced ICT networks increase Foreign Direct Investment (FDI) thus improving business prospects in countries at all levels of development.

While the effects are likely to be positive across all income levels, these effects are apt to be different depending on the income classes of the countries. In developing countries, fundamental public infrastructure – electricity distribution, sanitation, primary care and education systems – need to exist before many of the positive effects of Internet availability can have a significant impact on the economy. Low-income countries may not have sufficiently stable political and societal institutions for their populations to benefit significantly from access to the Internet. High and middle income countries have achieved levels of economic stability (they are higher up on the pyramid of Maslow's hierarchy applied to economies) and can attract investment in the communications infrastructure which can allow educational systems to more efficiently function, producing a more literate population.

In the context of this investigation, investing in Internet use can be seen as complementing both investment in human capital, as it makes workers more efficient by providing access to skills enhancing knowledge and more rapid ways to create, disseminate and assimilate information, and physical capital since it increases the productivity of physical capital. While this dissertation does not offer a growth story per se, it does provide evidence that Internet use positively impacts economic growth and other measures of development outcomes.

The focus of this dissertation is to provide empirical evidence of the causal relationship between increasing Internet use and increasing economic activity in a range of development outcomes. In this dissertation I focus on per capita GDP, exports, the size of domestic equity markets, and general welfare as measured by the HDI as indicators of development. As individuals and businesses within developing economics begin using the Internet, developing domestic economies will change. Individuals using websites and email to discover information on products and services will alter production and consumption patterns. Additional information flow regarding employment opportunities, production techniques, and new products will allow more efficient allocation of resources and deployment of human capital. While there are several development outcomes, I focus on these four partly because of their direct relationship to human welfare and partly because of data availability.

Growing and maturing domestic markets attract the interest of consumers in other countries increasing opportunities for trade. As more economic agents in both the public and private sector increase on-line presence, domestic equity markets become more accessible to global capital markets increasing both breath and depth of offerings in the market. Information flow is necessary for the efficient functioning of financial markets and this is critically important to emerging equity markets. Internet use provides perhaps the greatest enhancement to information creation and dissemination since the telephone and fax machine. Yartey (2008) investigates the effects of financial market structure and maturity on cross-border Internet diffusion and finds a significant link. This dissertation will expand on this line of investigation to explore the effects of increasing Internet use on domestic equity market size.

This dissertation demonstrates that Internet use does not provide the same marginal benefits to all countries. Providing Internet access and additional Internet users in the least developed countries does not significantly affect all aspects of economic development – it depends on the specific outcome being investigated. In middle-income countries, additional Internet users significantly increases all of the measures of economic activity under investigation in the study.

The results suggest that low-income countries have smaller, less significant, effects of additional Internet use on exports and market capitalization, while middle-income countries show large positive and significant effects. A 10% increase in Internet users increases per capita export revenues by 2.3% in middle-income countries, but has no effect (fail to reject the null hypothesis of no effect) on low-income countries. For per capita GDP, the results are noteworthy. Raising the number of Internet users by 10% is associated with statistically significant increases in per capita GDP of 3.2% in middle-income countries and an even greater 3.5% in low-income countries.

Since Internet use affects economic development outcomes differently depending on the country's income level, the policy recommendations must also vary according to the income level of the country. Additional Internet use has a significant positive effect on per capita GDP and on overall welfare as measured by the HDI on average in low-income countries. Thus, policy makers should focus on providing Internet access via low-cost mechanisms, such as cellular phone networks. As well, foreign direct investment can be directed toward developing the necessary infrastructure to allow greater Internet deployment while encouraging foreign aid to address health and education programs.

The most significant effects of additional Internet use occur in countries that have achieved middle-income status. Increasing Internet use has a positive and significant effect on all four measures of economic development in these countries. This suggests that policy makers in middle-income countries should focus on providing institutional and legal support to the service sector so that mobile banking, insurance, and other Internet enabled technological solutions can be delivered to the population via the mobile Internet. Countries with economies that are beginning to function and grow need widespread Internet connectivity to develop exports and domestic financial markets.

The remainder of this dissertation is organized as follows: Chapter 2 reviews the literature of relevant prior studies on economic growth, ICT, the Internet, and economic development in order to provide a basis for understanding the contribution of this dissertation. Chapter 3 provides the general theoretical model and empirical strategy for this study while Chapter 4 describes the data sources and discusses the variables used for the empirical investigation. Chapter 5 presents and discusses the econometric results of each investigation and Chapter 6 provides summary and policy implications of the results found and explores potential directions for future research.

2 Literature Review

There is a rich literature on economic growth but the relationship between economic development and ICT is just beginning to receive increased attention from academic researchers. Existing studies provide only a limited and partial view of the role that Internet use plays in economic development. The literature has focused primarily on the relationship between information use and the growth of income, neglecting other aspects of development. This dissertation provides a much broader view of the relationship between Internet use and development by investigating several mechanisms through which Internet use can affect the well-being of countries at different stages of economic development. This section of the dissertation discusses a selection of the existing research that provides the context for this dissertation.

While there are few published comprehensive empirical analyses of the role that Internet use plays on economic development, there are many important publications on the relationship between telecommunication generally and economic growth that provide a basis for understanding the contributions made by this study. I briefly mention a sample of studies dealing with the relationship between different aspects of development. The review is subdivided into the effects of ICT on several economic outcomes: growth, factor productivity, welfare, trade, and equity markets.

2.1 ICT, Development, and Economic Growth

The approach taken in this study follows the investigative method of using cross-country panel techniques found in Papakek's path-breaking work (1973) which isolates the effects of foreign direct investment (FDI), aid, and exports on economic growth. It is also similar to Barro's influential work (1991), which finds that human capital is positively related to political stability which, in turn, leads to economic growth. Levine and Zervos (1993) and later Sachs and Warner (1997) provide excellent surveys of the state of empirical cross-country growth research prior to the emergence of the Internet. These studies do not include ICT, Internet, or information mechanisms in their analyses of growth determinants. Neo-classical growth theory, based on the expanded Solow model, suggests that long-run growth is dependent upon labor force growth and technological progress (Grossman and Helpman 1994). This dissertation extends the literature by exploring the effects of Internet use, as a measure of technological progress, on a variety of outcomes including economic growth.

Recent studies have begun to explore the importance of institutions on economic development. Although both Acemoglu et al. (2001) and Rodrik et al. (2004) conclude that institutional quality is a critical determinant for economic development, neither study controls for technological factors that can enhance productivity, trade, and human capital development. Institutional quality is important to consider, as it helps explain differences in technological progress across countries. This dissertation controls for institutional quality, among other factors, in order to isolate the effects of Internet use on development outcomes. Interestingly, Audretsch and Keilbach (2007) introduce the idea of entrepreneurship capital, "the capacity for economic agents to generate new firms," as an important element of economic growth in Germany and find that ICT infrastructure is a significant component of entrepreneurship capital.

These studies all use institutions to explain differences in technical progress, while this dissertation takes institutions as a control variable in the investigation of the effects of new technology (specifically, Internet use) on development outcomes.

Banerjee and Duflo (2007) paint an extremely detailed picture of the difficulties facing the world's impoverished citizens. Technological solutions are often suggested as a means to enable poor populations find ways to increase income and improve their standards of living. Gulati (2008) argues that investment in ICT infrastructure for educational purposes may only benefit the already wealthy in low-income countries and suggests that basic educational services are perhaps of more immediate need. Gulati's opinion overlooks the overall welfare benefit that ICT access and Internet use provides to the population of developing countries by focusing on potential distributional problems. It may be difficult to imagine how aid packages that provide access to ICT and the Internet would be of immediate service to a population struggling to simply survive. However, while the poorest members of a population may not benefit directly, overall welfare is enhanced by ICT use. Once welfare is increased, redistributive policies can be implemented to help benefit the poor.

Rajan and Subramanian (2008) pursue further the question of the effects of foreign aid transfers on economic growth using dynamic panel data techniques and conclude that aid transfers are not significant to growth in a cross-section of countries. They control for endogeneity using a variety of instrumentation strategies. To balance this, Mishra and Newhouse (2009) find that direct economic aid does have a significant effect on health outcomes, measured by decreasing infant mortality rates, using the dynamic system GMM estimator. Increasing access to information via ICT and the Internet will likely have positive effects on health outcomes that may directly affect economic development, and indirectly affect economic growth, in countries with immature heath care systems. Neither of these studies investigate technological aid in the form of ICT infrastructure in general and Internet specifically. While this dissertation does not investigate the effects of economic aid directly, it is an important control in the empirical analysis and it is treated as endogenous.

The increasing availability of access to computers and Information Technologies (IT) in general began to have transformative effects on developed economies in the mid to late 1990's. DePrince and Ford (1999) focus their non-empirical study on the economic expansion in the United States as a result of the rapidly emerging Internet economy and conclude that "the emergence of the Internet economy is a Schumpeterian event that may rival the introduction of printing, steam power, the telephone and the assembly line as a growth enhancing innovation." Madon (2000) recognizes that the Internet will have important societal impacts in developing countries and provides a conceptual framework for understanding the interaction between the Internet and economic development. He suggests that there are "six key application areas of the Internet in developing countries, namely economic productivity, health, education, poverty alleviation and empowerment, democracy, and sustainable development." There are no published studies, that I am aware of, which empirically explores the effects of Internet use in all of these areas. I empirically investigate several dimensions of the effects of Internet on economic development suggested by Madon, with a specific focus on low and middle income countries as distinct classes. This dissertation, therefore, provides the most comprehensive empirical analysis of the relationship between Internet use and development that has even been done in one study.

Röller and Waverman (2001) investigate how telecommunication infrastructure affects economic growth in Organization for Economic Co-operation and Development (OECD) countries over a twenty-year period. After controlling for country fixed-effects and simultaneity, they find a significant causal effect of telecommunication infrastructure on aggregate output. Although this particular investigation focused on OECD countries, it may be possible that these effects can be found in countries at different levels of development. In this study, I control for government effectiveness as a way to proxy for institutional quality that can impact infrastructure deployment.

Jalava and Pohjola (2002) delineate three distinct ways ICT can enhance economic output in advanced economies. First, ICT goods directly contribute to output. Second, ICT capital is used in the production of other goods. And third, ICT-producing industries themselves contribute products and services. Using a macroeconomic growth accounting model, they find strong productivity enhancing effects of ICT in the United States in the 1990's, but weaker evidence in the other G7[6] countries. The effects are attributed to the globally competitive service industry in the US. They make no attempt to investigate the relationship in less developed countries.

Much research on economic development in the literature has focused on attempts to understand the low economic growth rates in Africa and other low growth regions. The potential contribution of ICT and the Internet to the growth process in Africa has not generally been a focus of the development literature. While this dissertation does not focus on Africa specifically, the results obtained from studying the effects of Internet use on developing economies provide additional information that can assist in understanding the developing economies in Africa.

Using stylized models based on data from the United States and Japan, Ernst and Lundvall (1997) explore what new institutions may be necessary for developing countries to leverage emerging IT solutions that may enhance learning. They suggest "for the majority of developing countries, the main concern is to create the necessary institutions that provide incentives and externalities necessary for domestic learning."

[6]The G7 is a group of seven industrialized nations whose finance ministers hold periodic meetings.

Important studies such as Acemoglu et al. (2001), Rodrik et al. (2004) and Banerjee and Duflo (2004) provide insights into the role of functioning institutions on economic growth in LDCs. Gyimah-Brempong (2000) finds adverse effects of corruption on growth in African countries during the 1990's using dynamic panel estimation techniques. Kalathil (2003) asserts that access to the Internet can help transform informal institutions to more formal institutions and can promote freedom in dictatorial regimes often found in LDCs. As events unfold across the Middle East and North Africa in 2011, it will be interesting to see if the unrest, fomented by communication through the Internet, leads to more transparent functioning institutions or if the autocratic regimes will simply restrict Internet access in order to preserve power.

Decker and Lim (2008) find that political institutions are significant determinants of growth. These studies do not investigate the effect of communication on institutions or the role of ICT in determining income growth. The free flow of information is critical to the creation and maintenance of effective institutions. For example, the free flow of information and transparency are both essential to effective and responsible governance. ICT and Internet use provides access to information that facilitates communication and this flow of information can only strengthen institutions.

In a recent study, Czernich et al. (2009) explore the effect of broadband Internet infrastructure on economic growth in OECD countries[7]. They use a technology diffusion model and instrumental variable techniques to demonstrate the positive causal effects of additional broadband Internet infrastructure in developed countries. The analysis is not extended to developing countries although there is no reason to limit the application of this model only to developed countries. This result highlights the causal relationship between enhanced Internet capacity and economic growth in developed countries. ICT capacity in developing countries can be thought of as simply

[7]Broadband is a technical name for high-speed or high-bandwidth Internet access.

the number of Internet users. This dissertation provides an analysis of the direct effects of additional Internet use on development outcomes in developing countries.

2.2 ICT, Internet, and Productivity

A number of studies investigate the productivity enhancement of ICT, IT investment and information networks. Dedrick et al. (2003) provide a comprehensive literature review of fifty prior firm and country level studies on IT investment and conclude that IT investment has a significant positive effect on labor productivity and economic growth. Although Engelbrecht and Xayavong (2006) find that ICT does not have a clearly positive effect on labor productivity in New Zealand, other studies provide contradictory results. Thompson and Garbacz (2007), using a stochastic-frontier production function estimation technique, find that information networks, which include mobile and fixed-line telephones and the Internet, benefit the world "as a whole" and some of the "poorest nations" by improving business efficiency and "institutional functionality."

Steinmueller (2001) concludes that ICT investment may allow "leapfrogging" or "bypassing some of the processes of accumulation of human capabilities and fixed investment in order to narrow the gaps in productivity and output that separate industrialized and developing countries." One example of this leapfrogging is the rapid adoption and deployment of cell phone networks to locations in developing countries where no fixed-line telephone infrastructure has ever existed. Ngwainmbi (2000) draws attention to the transformations that are necessary in Africa to adapt to the technological advances taking place around the world at the time of his study. The supplies of energy and telecommunication infrastructure are two critical areas necessary for Africa to participate in the global information marketplace. These studies and many others use casual observation, reason, and descriptive statistics as evidence to demonstrate the economic effects of the Internet. This dissertation provides an empirical investigation using econometric methods to better understand how the Internet effects economic development.

Goel and Hsieh (2002) provide sound economic reasoning, but no empirical analysis, to suggest that the Internet has the potential to promote competition and make markets more competitive by helping to remove information asymmetries. Parikh et al. (2007) consider how small-scale farmers can become better integrated into "global value chains" by utilizing a variety of technological solutions, but do so without providing empirical evidence. Goyal (2010) shows that rural soybean markets in India become more efficient when farmers are provided access to market price information via Internet kiosks.

Internet availability can help create and expand markets by allowing producers and consumers to connect and conduct trade in new ways. These studies provide solid reasoning as to how and why ICT and Internet access can enhance economic outcomes. What is missing in these studies is empirical evidence due perhaps to the lack of micro level data. This dissertation provides empirical evidence of the effects of Internet use on economic development using aggregate country-level data to fill this gap in the literature.

2.3 ICT, Internet, and Welfare

There is an expanding literature on the impact of ICT and the Internet on societal well-being. Crandall and Jackson (2001) and Prahalad and Hammond (2002) describe the significant opportunity for commercial firms to profit from providing goods and services – especially leveraging ICT infrastructure – to emerging markets in the underdeveloped countries around the world. While impoverished neighborhoods in Chicago may not be completely analogous to developing countries, the findings of Masi et al. (2003) that access to health information provided through the Internet empowered the poor residents in Chicago is an interesting result that may be equally applicable to LDCs. By exploring the effects of Internet use on a variety of economic measures and the UN HDI, this dissertation attempts to explore this relationship in the context of the developing world.

Jensen's fascinating and important study (2007) finds that when fisherman in India are provided cellular phones, price-dispersion in local fish markets is dramatically reduced, thus increasing both producer and consumer welfare. Thus, markets become more efficient with increasing access to information. Internet use provides a powerful means to increase information diffusion. This is one of the mechanisms by which Internet use influences economic outcomes in developing countries.

Shirazi (2008) studies ten Middle Eastern countries and concludes that ICT has a positive impact on promoting democracy and freedom of expression. The potent transformative power of populations connected through the Internet may underlie the popular uprising across North Africa and the Middle East in the early part of 2011. A deeper investigation of how access to ICT affects institutions and corruption is an interesting area for future research.

Some researchers argue, using reason and descriptive statistics alone, that ICT will have little impact on poverty alleviation and economic growth in LDCs. Kenny (2002) claims that until Internet access is simpler, less expensive, and literacy rates improve, "Internet as a tool for poverty alleviation should not involve programmes for universal access." He reiterates this belief that "LDCs appear ill-prepared to benefit from the opportunities that the Internet does present—they lack the physical and human capital, along with the institutions required, to exploit the e-economy" (Kenny 2003). Kenny suggests that there is evidence of the lack of significant effects of Internet use on income growth of the lowest income countries but he does not investigate this idea empirically. He suggests that providing aid for literacy, health and perhaps telephony may provide greater benefits to LDCs than providing Internet access. This dissertation extends these ideas by exploring the effects of the Internet based on a broad empirical analysis that isolates country clusters by income level in order to more deeply explore these claims.

Thompson and Garbacz (2007) find, like Kenny suggests, that expanding telecommunication networks enhances organizational efficiency in countries at all levels of development. More importantly, they explain that the poorest countries appear to benefit the most from the combination of institutional reform and expanding information networks. This is likely due to low penetration, which results in higher marginal product of telecommunication technology use. These results reinforce a thesis of this study that basic institutions and a stable social infrastructure must be in place before the gains from Internet availability can be realized.

Chinn and Fairlie (2007), using "a technique of decomposing inter-group differences in a dependent variable into those due to different observable characteristics across groups," find that per capita income has a positive relationship with Internet use, and suggest the existence of a potential simultaneity or reverse-causality problem with income and Internet use. By ignoring this potential endogeneity, the empirical results will be biased and inconsistent. While Chinn and Fairlie do not address the potential endogeneity problem, this dissertation uses dynamic panel data econometric techniques and controls for the endogeneity problems inherent in such cross-country empirical development research. The empirical results are described in detail in Chapter 5.

Aker and Mbiti (2010) explore the effects of expanding access to mobile phones on the quality of life in the low-income countries of Africa. Although not an empirical study, they conclude that access to mobile phone technology has the potential to expand economic development in sub-Saharan Africa. Studies such as this one provide explanations for the potential benefits of increasing ICT availability to developing populations, but they do not provide solid empirical evidence. This dissertation fills this gap in the literature by producing a comprehensive empirical investigation where none currently exists.

2.4 Internet, Trade, and Investment

One of the more well-developed areas of academic research on the economic effects of the Internet is in international trade and specifically exports. For developing countries, exports are an important means to create rapid economic growth.

Feder (1982) provides an analytical framework for exploring the growth effects of exports on a cross-country panel of LDCs between 1964 and 1973. His results suggest that export-oriented policies bring countries closer to optimal allocation of resources and increase marginal factor productivity enhancing economic growth in developing countries. Edwards (1998) uses a panel of 93 countries between 1960 and 1990 to explore the effects of economic openness (as measured by trade and policy indicies) on total factor productivity. He finds that more open economies experience faster productivity growth.

Zestos and Tao (2002) using time-series analysis on income, exports and GDP, find causal relationships between the growth rates of exports and imports and the GDP of Canada and the United States in a study focusing on these two countries, suggesting that exports may be a significant determinant of economic growth. Davies and Quinlivan (2006) finds evidence of a significant positive effect of increased trade on social welfare measured by the UN HDI in a cross-country panel. If Internet use increases trade, then it stands to reason that Internet use increases income growth through trade.

In their study of United States trade in services, Freund and Weinhold (2002) finds that increasing Internet penetration in a country increases both import and export growth. Specifically, a 10% increase in Internet penetration abroad is associated with a 1.7% increase in exports of services to the United States. In a subsequent study on international trade (2004) they find that access to the Internet (using Internet hosts[8] as a proxy) helps to explain trade growth. This 2004 investigation describes the calculated trade elasticity as "a 10 percentage point increase in the growth of web hosts in a country leads to about a 0.2 percentage point increase in export growth." They reason that fixed-costs are reduced and transportation costs for services are essentially eliminated with Internet use. Neither of these studies focus on developing countries nor do they attempt to address potential endogeneity problems and therefore do not conclude anything about causality. In the empirical investigation of the effects of Internet use on exports in this dissertation, an attempt is made to control for endogeneity using instrumental variable and dynamic panel estimation techniques.

Clarke and Wallsten's (2006) investigation attempts to understand to what extent the Internet stimulates trade between developing and developed countries. Their study finds that Internet access stimulates exports from poor countries to rich countries, but admits that the direction of causality is unclear. They offer an instrument for Internet users (a regulation dummy) to control for this potential endogeneity and find their results robust to endogenizing Internet penetration. Clark's recent work (2008) using firm-level data in low and middle-income countries in Europe and Cen-

[8] A host or server is a computer attached to the Internet that provides information to consumers.

tral Asia provides further evidence of the strong positive correlation, and argues for a causal relationship, between Internet use and exports.

Nair-Reichert and Weinhold (2001) use a mixed fixed and random effects estimation approach on a panel of 24 developing countries to investigate the effects of FDI on growth. They find evidence that increasing FDI stimulates growth in developing countries, but this effect is heterogeneous across countries. This suggests that studies that assume homogeneous effects may arrive at biased conclusions. This dissertation addresses the existence of heterogeneous effects on Internet use by investigating countries in sub-samples partitioned by income level.

Choi (2003) determines that there is strong evidence that increasing Internet use stimulates inward FDI. He reasons that Internet use boosts productivity and this increases the attractiveness of the country to external firms looking to make investments. Choi does not attempt to control for the possible simultaneous determination of FDI and Internet use or the potential reverse causal interpretation that increasing FDI leads to increased Internet use.

Reynolds et al. (2004) find that information infrastructure is a significant determinant of FDI in their preliminary investigation of all countries from 1975-1998. They use the number of telephone lines as the measure of infrastructure and attempt to control for endogeneity using a two-step residual estimator. Ko (2007) develops this further using dynamic panel estimators and concludes that in the presence of positive network externalities in developed countries, such as decreased connectivity charges and new electronic markets, increasing Internet usage attracts FDI. In developing countries, the presence of negative network externalities, such as network congestion, increasing Internet usage does not significantly increase FDI. Ko's approach of dividing countries into two samples, developed and developing, is similar to the one used in this dissertation. While most studies in the literature focus on the determinants of FDI, in this dissertation FDI is an important control variable in the empirical exploration of how Internet use effects economic outcomes.

2.5 Internet and Equity Markets

Recent empirical research on equity markets in developing countries has focused on the relationship between domestic capital markets and economic growth. Levine and Zervos (1996) evaluated an index of market strength on GDP growth using cross-country panel techniques and found evidence of a positive relationship but fall short of suggesting a conclusive causal effect. In contrast, Arestis et al. (2001) explores the relationship between stock market development and economic growth by analyzing five developed economies using a vector auto-regression (VAR) framework. They find that, while stock markets may contribute to overall growth, the influence of the banking system is greater in an absolute economic sense. Their findings suggest that "bank-based financial systems may be more able to promote long-term growth than capital-market-based ones" for the advanced economies studied.

Bekaert et al. (2001) investigate the impact of financial system liberalization on the prospects for economic growth in a sample of thirty developing countries. Their study concludes that liberalization of the financial system is associated with real economic growth. Although not a focus of the study, these results suggest that may be a relationship between financial market size and economic outcomes. This dissertation explores the effects of Internet use on financial market size and posits that capital market size is an indicator of improving economic conditions.

Schmukler (2004) develops the idea of financial globalization as "the integration of a country's local financial system with international financial markets and institutions." He reasons that developing countries can benefit from financial globalization, but strong institutions are critical for successful integration into the global financial system. Capital markets in developing countries are important to overall integration into the global economy. This dissertation shows how increasing Internet use can help to expand domestic equity markets that, in turn, can help facilitate economic integration into the broader global economy.

In a detailed case study of China, Shirai (2004) explores the role of the domestic equity market and economic development. He concludes that China's market does not provide the necessary support to encourage development since it fails in three specific functions: funds raised from market issues are not used productively, state ownership is too high in general, and accounting practices are questionable, making firm reports unreliable. This result may be from the limitations that the Chinese government places on the information available on the Internet. The Internet provides access to information and it is this free flow of information that allows for more efficient allocation of resources and capital.

Using a panel analytical approach to study the determinants of technology diffusion, Yartey (2008) finds that stock market development (measured by market capitalization to GDP) is significantly related to cross-country ICT diffusion. The study suggests that countries with a large domestic market capitalization pull ICT development investment from surrounding ICT enabled countries.

This dissertation contributes new analysis to the literature by presenting evidence that increasing Internet use increases market capitalization in developing countries. This may be explained by the increasing availability and transmission of information on domestic companies provided by Internet use which attracts interest from global investors. Another mechanism may be that increasing Internet use creates an attractive environment for new technology savvy businesses that use domestic equity markets.

2.6 Basis for this Dissertation

The research covered in this brief review of the literature provides a basis for understanding the contribution of this dissertation. These studies highlight the important aspects of economic growth, ICT, and economic development that are brought together in the exploration of Internet use and its effects on economic development in this dissertation. While there are numerous academic studies investigating aspects of economic development and ICT, this paper is the first comprehensive empirical investigation that provides a rich understanding of the causal relationship between Internet use and a diverse array of economic and welfare measures in developing countries.

3 Theoretical Framework and Estimation Methods

This chapter presents both a theoretical framework, which incorporates Internet use in a production functional form that can be used to study the measures of economic development of interest, and the two main empirical methods used to estimate the equations. The first section presents the theoretical framework while the second presents the estimation methods.

3.1 Model Specification

Internet use impacts economic development by providing the means to access, communicate, and use information. The Internet provides an efficient means to create, enhance, and move information that affects economic development in a number of ways, both directly and indirectly. As a direct input, access to information can lead to better decisions about production and more efficient allocation of capital and labor. Information can provide firms opportunities to benefit from economies of scale and scope by reducing search and transaction costs and expanding export opportunities. The Internet provides a new method for information acquisition and exchange allowing firms to discover new inputs and production technologies, learn about new potential markets for finished products and services, and find competitive prices for inputs leading to more efficient input ratios.

Existing studies in the literature suggest that increased information access through

Internet use enhances the productivity of labor and capital[9]. Access to the Internet provides advanced communication tools such as email and instant messaging which facilitates the exchange of ideas. This information exchange leads to knowledge, which is fundamental to technological progress. Thus information increases knowledge, hence increases human capital.

Similar to the presentation in Barro and Salai-Martin (2004) following Solow-Swan and Ramesy, I begin with a country's production function, F, for an outcome Y, during period t:

$$Y_t = A_t \cdot F(K_t, L_t, INET_t, X_t) \tag{1}$$

where Y_t is an economic outcome, A_t represents total factor productivity (TFP), K_t is the capital stock, L_t is labor, $INET_t$ is the number of Internet users, and X_t is a vector of controls which can include a variety of factors including institutional policy measures. In this dissertation I believe that Internet use, $INET_t$, positively affects development outcomes. Therefore, I posit that:

$$\partial Y_t / \partial INET_t > 0. \tag{2}$$

Following what is seen in the data, I model A_t as having both a deterministic and a stochastic component. The deterministic component corresponds to an underlying trend with a constant rate of growth, e^{gt}, while the stochastic component, e^{z_t}, yields random variations around the trend growth path that are assumed to follow an MA(1) process. Specifically,

$$A_t = e^{gt} e^{z_t}; \quad A_t > 0 \tag{3}$$

where z_t:

$$z_t = \rho z_{t-1} + \epsilon_t; \quad \epsilon_t \sim iid. \tag{4}$$

[9]See Choi (2003), Dedrick et al. (2003), and others.

Thus, e^{gt+z_t} describes the behavior of technological progress from advances other than the Internet[10].

This formulation captures the effects of both Internet use and exogenous technological progress. Internet access provides the ability to learn about new technologies. Additionally, access to the Internet facilitates the adoption and diffusion of new technologies as it provides a wide range of methods for communicating about the training and applications related to new technologies including, for example, email, websites, online forums, and shared academic courseware.

As seen from the prior studies in the literature review[11] ICT in general, and Internet use specifically, has been found to have a positive affect on economic output and factor productivity in countries at all levels of development to varying degrees. I extend this reasoning to explore the effects of Internet use on several different economic development outcomes.

Since economic theory does not provide an explicit functional form for (1), I consider the commonly used Cobb-Douglas *intensive* (or per capita) style production function incorporating the effects of Internet use, other technological progress, and the vector of controls:

$$y_t = A_t k_t^{\delta} inet_t^{\gamma} \left(\prod_{n=1}^{N} X_{nt}^{\zeta_n} \right). \tag{5}$$

Substituting (3) into (5) and taking the natural log yields:

$$lny_t = gt + z_t + \delta lnk_t + \gamma lninet_t + \sum_n \zeta_n lnX_{nt}. \tag{6}$$

Notice that this equation maintains both a trend component, gt, and a stochastic

[10] A potential problem with this specification is that this production function need not admit a steady state with constant growth. This is not an issue in the present context as I am considering levels.

[11] For example: Dedrick et al. (2003), Engelbrecht and Xayavong (2006), and Thompson and Garbacz (2007).

component, z_t. I model the trend and cyclical behavior as a time-invariant constant, α, plus the log of lagged realizations of the dependent variable, lny_{t-1}, and an *iid* stochastic shock, ϵ_t:

$$gt + z_t = gt + \rho z_{t-1} + \epsilon_t = \alpha + \beta lny_{t-1} + \epsilon_t. \tag{7}$$

Now substituting (7) into (6) and rearranging, I arrive at a log-linear model specification for an outcome y_j, in country *i,* during time period *t:*

$$lny_{jit} = \alpha + \beta lny_{ji,t-1} + \gamma lninet_{it} + \delta lnk_{it} + \sum_n \zeta_n lnX_{nit} + \epsilon_{it}. \tag{8}$$

In this generalized log-linear model specification, y_{jit} is a particular per capita development outcome indexed by j, $inet_{it}$ is now per capita Internet use and is the primary explanatory variable of interest – the number of Internet users in country i during time t – with coefficient γ. β is the coefficient of the lagged outcome variable $lny_{ji,t-1}$. k_{it} is per capita capital stock with coefficient δ, X_{nit} is one of n row vectors of control variables with coefficient ζ_n, α is the intercept, and ϵ_{it} is a stochastic error term.

The variables in the vector X can vary depending on the particular development outcome being investigated and will be defined for each equation. However, for three of the four models explored in this dissertation, the control variables are identical. This model uses log-linear models as the log transformation narrows the range of the data and reduces the sensitivity of the resulting estimates to outliers. Also importantly, the coefficients on the log-log equations can be easily interpreted as elasticities thus allowing for the direct comparison of the effects of Internet use on several economic development outcomes.

This dissertation is primarily concerned with the sign, magnitude and statistical significance of the coefficient, γ, on the measure of Internet users in all of the estimation equations for each development outcome. The coefficient on the lagged dependent variable β, is expected to be positive, less than one, and statistically significant in the presence of dynamics. The hypothesis of this study is that the elasticity of Internet use, γ, will be non-negative with different magnitudes and significance depending on the development outcome being investigated and particular sub-sample used.

The literature on economic development tends to utilize models where the investigated outcome is a function of GDP[12]. In this dissertation I present a general model specification that can be used to empirically investigate several different economic development outcomes, one of which is GDP. This approach does not include GDP as a control (for other outcomes), as I am considering GDP as an economic development outcome measure that is explained by the same controls as other measures. In fact, I believe this model specification may be useful to explore additional development outcomes that I will consider in Chapter 6.

The general log-linear estimation equation for the three per capita outcomes under investigation here is:

$$lny_{jit} = \alpha + \beta lny_{ji,t-1} + \gamma linet_{it} + \delta lcap_{it} + \zeta_0 laid_{it} + \zeta_1 secsch_{it} + \zeta_2 lifexp_{it} + \zeta_3 inst_{it} + \epsilon_{it}. \tag{9}$$

In this specification, *lny* is a logged per capita economic outcome indexed by j, *linet* is the natural log of per capita number of Internet users, *lcap* the natural log of per capita fixed capital formation, *laid* natural log of per capita net foreign aid, *secsch* is the secondary school duration in years, *lifexp* is life expectancy at birth in years, and *inst* is a measure of institutional quality. The variables selected as controls are those commonly used in growth and development empirics as proxies for the critical

[12] See, for example: Freund and Weinhold (2002), Clarke and Wallsten (2004), Yartey (2008) and Clarke (2008).

components of economic development: fixed capital formation, foreign aid, education, health, and institutions. There is no control for labor, as these models are estimating per capita outcomes.

The choice of control variables is supported by a wide range of empirical studies in the literature. Controls for capital formation and aid date back at least to Papanek's path-breaking paper on the determinants of economic development (1973). The literature on economic growth is full of studies that include controls for human capital using educational attainment and health measures as proxies. For example, secondary schooling entered into growth equations in two influential growth papers: Barro (1991) and Mankiw et al. (1992). Life expectancy is a common proxy for health attainments as in Sachs and Warner (1997). As previously covered in the literature review above, several important papers have highlighted the role of institutions in economic development, including Acemoglu et al. (2001), Rodrik et al. (2004) and Banerjee and Duflo (2004). An in-depth discussion of data sources and the specific control variables selected can be found in Chapter 4.

The log-linear model for logged per capita GDP, *lgdp*, follows the general model in (9):

$$lgdp_{it} = \alpha + \beta lgdp_{i,t-1} + \gamma linet_{it} + \delta lcap_{it} + \zeta_0 laid_{it} + \zeta_1 secsch_{it} + \zeta_2 lifexp_{it} + \zeta_3 inst_{it} + \epsilon_{it} \tag{10}$$

Using this method to estimate the effects of ICT on exports is somewhat of a departure from the approaches commonly found in the literature. Empirical estimates of export growth normally include some measure of GDP as a control[13]. In this dissertation I am exploring a range of economic outcomes influenced by the same conditioning factors as GDP. As such, I estimate the effects of Internet use on each of

[13]See Freund and Weinhold (2004) and Clarke (2008) for example.

these measures using the same model. The log-linear model, therefore, for per capita exports, *lexp*, follows the same pattern as general estimation equation (9) and the per capita GDP equation (10) above:

$$lexp_{it} = \alpha + \beta lexp_{i,t-1} + \gamma linet_{it} + \delta lcap_{it} + \zeta_0 laid_{it} + \zeta_1 secsch_{it} + \zeta_2 lifexp_{it} + \zeta_3 inst_{it} + \epsilon_{it} \tag{11}$$

This builds upon well established models and extends them to explore the effects of Internet use on exports[14].

There is little empirical research on the determinants of capital markets in developing countries. As presented in the literature review, most studies focus on financial markets as a determinant for economic growth rather than investigating the factors that determine financial market expansion[15].

Considering the size of domestic equity markets as an economic development outcome is a new concept explored in this dissertation. I argue here that the same model used to explore other outcomes, such as GDP and exports presented above, can be used to explore the effects of Internet on market capitalization. Arbitrage Pricing Theory extended the Capital Asset Pricing Model (CAPM) in order to explore how multiple factors influence the pricing of individual equities[16]. Here, I am expanding this idea and incorporating it into existing models – such as those used by Holzmann (1997), Perotti and van Oijen (2001), and Bekaert et al. (2001) – to explore the effects of Internet use, conditioning on multiple economic development factors, as a determinant of market capitalization. Thus, the estimation equation for per capita market

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[14]See for example: Balassa (1985), Hossain and Karunaratne (2004), and Young (1991).

[15]For example: Levine and Zervos (1996), Bekaert et al. (2001), and Yartey (2008).

[16]See: Ross (1976) and Roll and Ross (1980).

capitalization, *lmcp*, is expressed similarly to the above equations:

$$lmcp_{it} = \alpha + \beta lmcp_{i,t-1} + \gamma linet_{it} + \delta lcap_{it} + \zeta_0 laid_{it} + \zeta_1 secsch_{it} + \zeta_2 lifexp_{it} + \zeta_3 inst_{it} + \epsilon_{it} \tag{12}$$

For all three of the above estimation equations, I expect the coefficients on fixed capital formation, education, health, and institutions to be positive. The influence of aid on economic development is an area of current debate, but I expect a negative coefficient, as poor performing countries attract more aid. This is one of the endogeneity problems discussed in the estimation methodology section below. For all equations, I expect the coefficient on Internet use to be positive and significant for all income stratifications except for the low-income countries.

The UN Human Development Index (HDI) is a composite index that includes several welfare measures: life expectancy at birth, the adult literacy rate, an education enrollment ratio, and GDP per capita (United Nations 2008). It was measured every 10 years from 1980 to 2000, and then in 2005 the UN began calculating the measure annually. This dissertation used interpolated values for the HDI to add observations for the missing years covered in the sample. Because the HDI is a composite of a number of other development indices, it cannot be modeled in the same way as the other equations.

The model for the estimation of the effects of Internet use on HDI is of a different form due to the nature of the index and when it is measured. While there is undoubtedly dynamics in the underlying components of the HID, the index has not historically been measured annually or at regular intervals; the measurement period has varied over the time the index has been developed. As such, this model does not use a lagged dependent variable.

The HDI equation is log-linear and the controls are not per capita as per capita control measures may produce biased estimates due to the fact that we do not have sufficient information to accurately measure covariates in per capita terms. Here, *linetto* is the total number of Internet users, *lcaptot* is the total fixed capital formation, and *laidtot* is the total amount of international assistance (all in current US dollars.) The proxies for health and educational attainment are removed as those are components of the index, and a control for the size of the labor force, *llabor*, is added.

$$hdi_{it} = \alpha + \gamma linettot_{it} + \delta lcaptot_{it} + \zeta_0 laidtot_{it} + \zeta_1 llabor_{it} + \zeta_2 inst_{it} + \epsilon_{it} \qquad (13)$$

As in the estimation equations for GDP, exports, and market size, I expect the coefficient on γ to be positive and significant in the middle-income sample. The elasticities on capital formation and institutional strength are expected to be positive, while those for aid and labor are expected to be negative.

The model specifications used in this dissertation are intuitively appealing as they capture the important elements from influential growth and development empirical works in the literature. These specifications adopt, adapt, and extend the common specifications in order to explore the causal effects of Internet use on various measures of economic development activity. By combining the important elements of the model specifications from throughout the growth and development literatures, I provide a consistent empirical framework for evaluating the range of economic development outcomes presented in this dissertation, and others to be explored in the future.

3.2 Estimation Methods

There are two potential sources of endogeneity in these models. They are the direction of causality of Internet use and the endogeneity of economic aid. Increasing domestic production and productivity, recorded by the per capita GDP, can certainly cause an increase in Internet availability and use as individuals with more disposable income become more sophisticated in their demands for products and services and firms modernize using increased profits. In a similar way, poor production (low per capita GDP) will engender additional aid. These sources of endogeneity in these models imply the need to use estimation methods that account for endogeneity in order to provide identification of a causal connection between Internet use and economic development. This dissertation extends the prior development and ICT literature by addressing these problems of endogeneity, as well as, the presence of dynamics, which creates problems for the use of the common panel estimators.

Estimation by Ordinary Least Squares (OLS) is the de facto starting point for empirical economic analysis. It can provide good first approximations for the marginal effects of the variables under investigation. This model specification can be estimated easily by stacking the equations and using pooled ordinary least-squares. OLS estimation allows identification of parameters of interest provided the conditional mean is correctly specified, the errors are independent and identically distributed, and there is no multicollinearity in the regressors. But, OLS estimation is biased and inconsistent in the presence of endogeneity and dynamics –when there is correlation between the error term and any of the the regressors– which is likely to occur in cross-country panels when studying aggregated macroeconomic measures as some of these measures are likely simultaneously determined. The equations specified above are dynamic in that they have lagged dependent variables and several control variables may be endogenous.

Using OLS to estimate (9) will lead to problems from the fact that the lagged realization of the dependent variable is correlated with the country fixed-effects. A shock to a country in the prior period will affect both the lagged realization and the country effect. This violates an OLS assumption. A common approach in the social science literature to deal with this problem is to transform the estimation equation to remove the fixed-effects by time de-meaning the data and estimating the model on the time-demeaned data using OLS, this is fixed-effects (FE) estimator. The error term in the FE regression model, $(\epsilon_{it} - \overline{\epsilon}_i)$, will be correlated with the response variable, $(y_{it} - \overline{y}_i)$, since y_{it} is correlated with ϵ_{it} which is the same problem from the OLS estimation. Although fixed-effects estimation does not address the endogeneity problem, fixed-effects estimates for all of the models are included for comparison.

To control for the endogeneity present in the model, more advanced econometric techniques are necessary. Using equations derived from (8), two additional estimation approaches are used in the empirical investigation in this dissertation. The first uses Dynamic Panel Data estimation, the predominant cross-country panel data estimation technique used in the literature, to deal with Internet use and aid endogeneity and dynamics of the response variable. The second approach uses Finite Mixture Model estimation to investigate the response variables as draws from a distribution composed of collections of distinct continuous distributions of sub-populations.

3.2.1 Dynamic Panel Data (DPD) Estimation

The Dynamic Panel Data estimators, or more specifically the Dynamic Panel System and Difference General Method of Moments (GMM) estimators, are commonly used in the literature to estimate models on cross-country data when dynamics and endogeneity are present[17]. These estimators are preferred for three reasons, well articulated by Bandyopadhyay et al. (2011). First, it is important to capture the persistent effects of Internet use in a dynamic framework. Second, there are important endogeneity

[17] See, for example, Caselli et al. (1996), Hoeffler (2002), Gyimah-Brempong and Karikari (2007), Rajan and Subramanian (2008), and many others.

concerns with respect to Internet use, economic aid, and the measures of development outcomes under consideration. Without well identified and understood instrumental variables, two-stage least squares techniques are unavailable. And third, it is important to control for unobserved country heterogeneity that may be correlated with the investigated outcomes.

Following Cameron and Trivedi (2005), if we return to the generic autoregressive model specified above in equation (8):

$$y_{it} = \alpha + \beta y_{i,t-1} + \gamma linet_{it} + \delta k_{it} + \sum_{n} \zeta_n X_{nit} + \epsilon_{it} \tag{14}$$

where the error term ϵ_{it} is composed of η_i, representing time-invariant country specific effects, and u_{it}, an idiosyncratic error that varies across countries and time periods:

$$\epsilon_{it} = \eta_i + u_{it} \tag{15}$$

with:

$$E[\eta_i] = E[\epsilon_{it}] = E[\eta_i u_{it}] = 0 \tag{16}$$

then the autoregressive model can be specified:

$$y_{it} = \alpha + \beta y_{i,t-1} + \gamma linet_{it} + \delta k_{it} + \sum_{n} \zeta_n X_{nit} + \eta_i + u_{it}. \tag{17}$$

The two frameworks used to control for η_i are the fixed effects (FE) and random effects (RE) models. Fixed effects, or within, estimation assumes η_i is a country-specific constant in the regression model, while random effects, or between, estimation takes η_i to be a country-specific disturbance in each time period. The fixed effects approach assumes correlation between the unobserved heterogeneity and the regressors in X, while the random effects approach assumes that η_i is uncorrelated with X in all time periods. These panel estimation techniques provide consistent estimates provided all explanatory variables are strictly exogenous, which is not the case here.

An estimator that produces consistent estimates in the presence of dynamics and endogeneity is required. Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998) have proposed and extended dynamic GMM panel estimation techniques that use the linear moment restrictions implied by the above dynamic panel estimation equation[18]. The DPD is an instrumental variable GMM estimator that uses lagged differences of the dependent variables and endogenous regressors and current values of strictly exogenous regressors as instruments.

The system DPD GMM estimator is preferred to the difference estimator in this application since it can magnify gaps in unbalanced panels. This motivates the forward orthogonal deviations transformation (used in the estimation of the models in this dissertation) that "instead of subtracting the previous observation from the contemporaneous one, subtracts the average of all future available observations of a variable. No matter how many gaps, it is computable for all observations except the last for each individual, so it minimizes data loss" (Roodman 2006). The two-step estimator is preferred over the less efficient one-step estimator in the presence of non-spherical errors and since I suspect that models with endogenous regressors and dynamics will have non-spherical errors, I use the two-step variant.

The standard DPD statistical tests of overidentification restrictions and serial correlation of the errors terms are used to evaluate the robustness of the resulting estimates. The test statistics are reported in tables following the regression results for each model in the appendices.

[18]Bond (2002) provides an excellent treatment of the development of these DPD estimators.

3.2.2 Finite Mixture Model (FMM) Estimation

In this dissertation, I assume that Internet use effects countries differently based on their level of economic development and that there are three distinct categories of development that can be identified by the World Bank country income classification: low, middle, and high income. This implies that there is some homogeneity within each of the three particular income classes that can allow for the investigation of each income class separately. The assumption that there are a finite number of relatively homogeneous classes that describe the distribution of outcomes under investigation make this estimation problem well-suited to using Finite Mixture Model (FMM) techniques.

The FMM estimation technique models unobserved heterogeneity by positing that the variable of interest is drawn from a distribution that is composed of an additive mixture of distributions from distinct sub-populations or classes. Although FMM estimation is not yet common to the development literature, it is being used in some economic applications[19]. Mixture modeling is attractive in the sense that it provides a different way to model heterogeneity.

Owen et al. (2009) apply FMM estimation to explore the question of country growth rates. They test several latent class predictors (a settler mortality instrument for institutions, a latitude measure, and a indicator for the landlocked status of a country) and models with two to five different classes. They find that institutional quality is the best predictor, of the ones used, and a two class model best fits the sample used. Their conclusion is that single class pooled analysis overlooks country growth rate heterogeneity. Unlike their approach, I am positing the latent class

[19] See, for example, Deb and Trivedi (1997), Conway and Deb (2005), Owen et al. (2009), and Munkin and Trivedi (2010).

membership is based on income level.

Although I have assumed a finite number of classes that account for country heterogeneity, Cameron and Trivedi (2005) suggest that the identification of the specific, potentially latent, classes can be problematic without some natural interpretation. I am assuming here that the effects of Internet use on economic development outcomes vary based on the income level of the country and therefore, the latent classes have a theoretical basis in that they correspond directly to the World Bank country income classifications.

The FMM estimation method models a different distribution for each class and, while it does not directly address endogeneity and dynamics problems, it can model the different elasticities across income classes. The component densities for each class – low, medium and high income – are represented in proportions π_c where:

$$\sum_{c=1}^{3} \pi_c = 1, \;\; 0 < \pi_c < 1 \, \forall \, c = 1, 2, 3 \tag{18}$$

and π_c is modeled:

$$\pi_c = \frac{\exp(\tau_c)}{\exp(\tau_1) + \exp(\tau_2) + \exp(\tau_3)} \tag{19}$$

The densities of the economic measures in this study can be generalized as a probabilistic mixture of the densities from the three income classifications (or components.) This is expressed by the following equation:

$$g\,(y \mid \Theta) = \pi_1 g_1\,(y \mid \Theta_1) + \pi_2 g_2\,(y \mid \Theta_2) + \pi_3 g_3\,(y \mid \Theta_3) \tag{20}$$

where π_c is the proportion of the mixture density as described above and $g_c\,(y \mid \Theta_c)$ is the individual class density of the variable y given the parameter vector Θ_c. Each individual class density is normal by construction and can be described by the following equation where the mean of the distribution for the income class is found using equation (8):

$$\mu_c = lny_{jit} - \beta lny_{ji,t-1} - \gamma linet_{it} - \delta lnk_{it} - \sum_n \zeta_n lnX_{nit} \tag{21}$$

$$g_c\left(y \mid \Theta_c\right) = \frac{1}{\sqrt{2\pi\sigma_c^2}}\, exp\left(\frac{-1}{2\sigma_c^2}(\mu_c)^2\right) \tag{22}$$

This equation is not directly estimated, rather the linear estimation equations, derived from (8), provide the parameters for the means of the individual class distributions used for mixing. This estimation technique allows for the mixing probabilities, regression coefficients and standard deviations, σ_c, all to vary per class. The model is estimated using maximum maximum likelihood estimation with specified mixing probabilities based on each country's income classification[20]:

$$\max_{\pi,\theta} \ln L = \sum_{i=1}^{N}\left[\ln\left(\sum_{c=1}^{3}\pi_c g_c(y_c \mid \Theta_c)\right)\right]. \tag{23}$$

Once the models have been estimated, the elasticities (or marginal effects) are calculated at the means of the covariates specified in the models. These values are interpreted in the same way as the coefficient estimates from the OLS and DPD estimators. Estimating each of the models using FMM provides a robustness check to the model specifications as I expect to find a similar sign, magnitude, and significance for the elasticity on Internet use regardless of the estimation method.

[20]Code from Deb (2008) is used for the estimation.

4 Data Sources and Panel Construction

In order to conduct an empirical investigation of the ways in which Internet use has impacted economic development around the world, several different socioeconomic measures are required. Data on Internet use, macroeconomic measures, government institutional effectiveness and population health status are all necessary to complete this investigation. Several data sources were required in order to construct the panel used in the empirical analysis.

This study focuses on the years 1996 to 2007, the period of rapid growth in Internet use world-wide. This period is selected for two important reasons. First, data on Internet use in general, and on low and middle income countries specifically, prior to 1996 are not widely available due to the low penetration rate of the Internet outside of a few developed countries. Second, at the time of writing, available data sources provide information on Internet use for a large number of countries only go through 2007. Although some observations exist for 2008 and 2009 in the data utilized, the data coverage is not complete for most countries. As such, observations beyond 2007 are excluded from the economic estimates.

The main explanatory variable of interest for this study is the number of Internet users in a country. The GDP, exports, aid, and fixed capital formation measurements are measured current US Dollars. Per capita measured are created by normalizing all four of these variables by the population. The health proxy measure is life expectancy at birth in years, and the educational attainment measure is the duration of secondary school in years. Institutional quality and the HDI are both indicies used to measure the the quality of institutions and overall wellbeing respectively. Each variable will be covered in detail in the following sections on the particular data sets from which they were taken.

The robustness of any empirical analysis depends on the quality of the data available and this study is no exception. All data sources utilized in this investigation contain aggregated country level data. As this study investigates aggregate country-level phenomena, data that has been combined for each country and year is appropriate. There is undoubtedly measurement error in these data but, as these are the primary sources for cross-country panel studies in the economic literature, we rely on the assumption that the errors are random and not systemic and therefore do not introduce bias into the samples.

Four primary data sources were selected to provide the macroeconomic measures needed for this study. The resulting panel, fused from theses data sources, contains information on 202 countries with observations on economic, societal, governance, communications and health variables covering the period 1996 to 2007. Table 1 contains the identifier, description and examples of use in the literature on the variables utilized in this study. Descriptive statistics of the full sample and the low and middle income sub-samples are provided in Appendix B. Histograms of the key measures used in this study can be found in Appendix C. The following sections provide brief overviews of the four data sources and the variables drawn from those datasets used in this dissertation.

Table 1: Variables used in this study

Variable	Definition	References	Source
linet, inettot	The number of Internet users per capita and total	Freund and Weinhold (2002); Freund and Weinhold (2004); Gyimah-Brempong and Karikari (2007)	ITU/ICT
lgdp	Natural log of GDP, per capita (USD)	Common; Acemoglu et al. (2001); Barro (2001); Bhattacharyya (2009); Kenny (2002)	WDI
lexp	Natural log of export revenues of goods and services, per capita (USD)	Freund and Weinhold (2004)	WDI
lmcap	Natural log of market capitalization, per capita (USD)	New in this study	WDI
hdi	UN HDI: measure of development level	Common; Davies and Quinlivan (2006)	UN HDI
laid, laidtot	Natural log of net Aid, per capita (USD) and total: measure of perceived domestic problems	Gyimah-Brempong and Karikari (2007)	WDI
lcap, lcaptot	Natural log of the fixed capital formation, per capita (USD) and total	Common	WDI
lifexp	Life expectancy at birth (years): proxy for health status	Common	WDI
secsch	Secondary education, duration (years): proxy for educational attainment	Common	WDI
llabor	Natural log of the total labor force size	Common	WDI
inst	Equally weighted average of five measures from the WGI: control of corruption, government effectiveness, political stability, regulatory quality, and rule of law	Andrews (2008);(Decker and Lim 2008)	WGI
incomecode	Coding for World Bank income classification	Common	WDI

4.1 International Telecommunications Union: ICT Indicators

The 2008 International Telecommunications Union World Telecommunication ICT Indicator (ITU/ICT) is recognized as the one of the most comprehensive source of data on telecommunications available. This database provides detailed indicators on Information and Communication Technologies throughout the world. "The data are collected from an annual questionnaire sent to official country contacts, usually the regulatory authority or the ministry in charge of telecommunication and ICT (International Telecommunication Union 2008)."

The main explanatory variable of interest for this study, the number of Internet users in a country, is drawn from this data set. Although there are other measures used is the literature to understand the effects of the rapid growth of the Internet, the number of Internet users per capita (or the percent of the population with Internet access) provides the granularity of detail desired for this investigation.

4.2 World Bank: World Development Indicators

The World Bank World Development Indicators (WDI) 2009 (World Bank 2009) is the preeminent data source for empirical development economic investigation and was selected to provide the comprehensive measures of economic activity covering hundreds of development indicators on 208 countries covering the years of interest: 1996-2007. This data set supplies the macroeconomic indicators and income group classifications on the 202 countries that are used in this study. Six countries were dropped from the WDI data set due to limited data or questions regarding the consideration of them as independent countries: Hong Kong, Macao, Puerto Rico, US Virgin Islands, American Samoa and West Bank and Gaza.

Most of the economic measures used in this study are from this data set. The indicators of GDP, export value, and domestic equity market capitalization provide a range of measures of economic activity through which a comprehensive exploration of the effects of Internet use can be conducted. Several measures from this data set are used as controls. Net foreign aid provides the means to control for external economic influences. In order to control for domestic investment, fixed capital formation is used. All of these measures are normalized by the population size to create per capita measures to mitigate the potentially skewing effect of very large countries.

All financial indicators are in current year U.S. dollars. Current year exchange rates are used to convert from the local currency into U.S. dollars. The GDP, exports, and fixed capital formation measurements come from World Bank national accounts data. Net official aid amounts are derived from Organization for Economic Cooperation and Development (OECD) information. Market capitalization figures come from Standard & Poor's data.

In order to control for health status within the countries under investigation, I use the life expectancy at birth measured in years. This measure comes from United Nations Population data. Educational attainment is proxied by the duration of secondary education in a country also measured in years (or grade levels.) The World Bank uses United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics data for educational measures. Life expectancy and secondary school duration are two common measures for health and education used throughout in the development literature.

The income classification provided by the World Bank for each country serves as the means to stratify the sample in order to isolate the effects of Internet on countries at different levels of development. Countries are sorted into one of three income levels, with high and med being sub-grouped into upper and lower.

> Economies are divided according to 2009 Gross National Income per capita, calculated using the World Bank Atlas method[21]. The groups are: low income, $995 or less; lower middle income, $996 - $3,945; upper middle income, $3,946 - $12,195; and high income, $12,196 or more World Bank (2009).

In this study, I create use these income levels to create three sub-samples: low, middle (composed of lower and upper middle), and high income.

4.3 World Bank: Worldwide Governance Indicators

The World Bank Worldwide Governance Indicators (WGI) combines aggregated data on 212 countries from 1996-2007 on six dimensions of governance: Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law and Control of Corruption. "These aggregate indicators are weighted averages of the underlying data, with weights reflecting the precision of the individual data sources (Kaufmann et al. 2009)."

This investigation follows Decker and Lim (2008) and uses an equally weighted average of five of the WGI components as a proxy for the maturity and stability of government institutions. The component omitted from the weighed average is the Voice and Accountability measure, which may be a more appropriate proxy for democratic representation in government rather than of the strength of institutions within the country.

[21] More information on the World Bank Atlas method can be found on the World Bank website: http://data.worldbank.org/about/country-classifications/world-bank-atlas-method.

It is clear from the body of empirical evidence in the literature that functioning government institutions are necessary for economic development in developing countries[22]. In order to provide ICT infrastructure and make Internet access available to its population, a government must have functioning institutions. The constructed index is a measure of institutional effectiveness and an important control for the empirical investigations.

4.4 United Nations: Human Development Index

The United Nations Development Programme's – 2008 Human Development Index (HDI) is a composite measure of education, literacy, and income on 176 countries calculated in 1995, 2000 and 2003-2007 published by the United Nations Development Programme.

> The HDI – human development index – is a summary composite index that measures a country's average achievements in three basic aspects of human development: health, knowledge, and a decent standard of living. Health is measured by life expectancy at birth; knowledge is measured by a combination of the adult literacy rate and the combined primary, secondary, and tertiary gross enrollment ratio; and standard of living by GDP per capita (PPP USD) (United Nations 2008).

The UN HDI measure is used in order to consider the broadest measure of economic development and population well-being.

Since the UN HDI is not calculated every year, the sample size is significantly reduced when using this indicator as a response variable. In order to expand the ob-

[22]See Acemoglu et al. (2001), Rodrik et al. (2004) and Banerjee and Duflo (2004).

servations available for the empirical analysis, cubic spline interpolation techniques[23] are used to construct missing observations for years where the UN did not calculate HDI values. The descriptive statics presented in Appendix B provides information on both the original indices and on the expanded measures after interpolation and extrapolation.

4.5 Panel Construction

The panel created for the empirical investigation in this dissertation contains variables from all four data sets described above. Every country observation in each data set is assigned a consistent numerical value based on the UN country name and the World Bank three-character country code identifier to facilitate merging. Each individual panel is first processed to eliminate unneeded variables, correct formatting, and set the shared numerical country identifiers prior to panel construction.

The two World Bank data sets require very little processing to prepare for integration into the panel. Some countries in the WDI database are missing region identifiers and that information must be added prior to the merge.

The UN WDI and ITU ICT databases both require reshaping prior to integration. Reshaping refers to the reorganization of panel data from *long* format, where variable entries are separate observations, to *wide* format, where all variables for a particular subject are contained in the same observation. Panel econometric investigation is more commonly done on *wide* panels, as is the case in this study. Reshaping was done using custom Python[24] scripts to read comma-delimited files of data from

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[23]A mathematical procedure to fit a smooth curve to a discrete number of observations. This is accomplished using the *cipolate* command in Stata 11 (Cox 2002).

[24]Python is a general purpose programming language. More information on Python can be found at http://www.python.org/.

the respective sources, accumulate and reorganize the information, and output new comma-delimited files that can be used for econometric analysis.

Once the merger of the four primary data sets was completed, the indicator variables for region and country income levels were created. Last, the logged per capita values of the variables of interest were created.

4.6 Variables and Sample Stratification

All estimations are run on the full sample and on reduced samples with the countries stratified by income level. The 2007 World Bank income level[25] is used to partition the countries into high, medium and low income categories. A variable *incomecode* is introduced to reflect this coding. Although the World Bank creates five income sub-categories, beyond the three primary categories, I use the three main categories, High, Medium, and Low Income, to identify the sub-samples for this study.

Each model is estimated for the full sample and each of the three sub-samples. Comparisons of the coefficient on the variable of interest, *linet,* the natural log of the number of Internet users per capita in a given country and year, from the regressions on each sample are then made. Log transformations are used in this study for several important reasons. Taking the logs of observations narrow the data range and reduce the sensitivity of the models to outliers. Also, the coefficients on the log transformed estimated equations can be interpreted as elasticities.

Data availability is a serious constraint particularly for empirical evaluations of less developed countries. This problem exists for many of the countries in the early years in the sample created for this study. Further, observations are missing on some

[25] Appendix A contains the list of countries by World Bank income category.

economic measures at different years throughout the period under investigation.

4.7 Summary Statistics

The entire data set includes indicators on 202 countries from 1996 to 2007. The maximum possible number of observations if all of the indicators were available for all countries and for every year would be 2,424. Most variables have good coverage over the years of interest in the sample with the exception of the market capitalization measure and the UN HDI.

The summary statistics suggest that Internet use varies significantly in the panel and sub-samples in that the standard deviation is several times larger than the mean. This is likely due the rapid change in Internet use over time.

Appendix A presents a list of the countries included in this study organized by World Bank income classification. Appendix B provides summary statistics on the three samples under investigation: the full data set, the sub-sample of middle-income countries, and the sub-sample of low-income countries and Appendix C provides histograms of the data distributions for the primary variables of interest.

5 Empirical Results

The main objective of this dissertation is to test the effects of Internet use on four different development outcomes: per capita GDP, exports, equity market size, and a composite measure of human welfare as proxied by the UN HDI. This chapter presents the empirical results of estimating the four models described in Chapter 3 on the entire multi-country panel data set and three sub-samples based on income level (high, middle, and low) from the data set described in Chapter 4.

In Chapter 3 I discussed the theoretical basis for the empirical investigation and showed that, in the estimated equations presented, there is the presence of dynamics and endogeneity. As such, the DPD estimator is the most appropriate as it can account for these conditions. It is possible that the error disturbances of the effects of Internet use on these outcomes differ according to income class. Under these conditions the FMM estimator provides an alternate means to evaluate the effects of Internet use, using the income classes as distributions and modeling the distribution of the outcomes as a mixture of the component distributions. I therefore use the FMM estimator to estimate the equations as a robustness check. For comparison, I have also included the results from the OLS and FE estimation of all equations.

The consistency of the DPD GMM estimator depends crucially on the presence of first order autocorrelation and the lack of second order autocorrelation in the error terms. Therefore, the results of the Arellano-Bond tests for first and second order autocorrelation in the errors are reported for each estimated equation.

The Arellano and Bond system GMM DPD estimator uses lagged values of the endogenous variables as well as current and lagged values of the exogenous regressors as instruments in the differenced equation. In all of the following models, Internet use, aid, and life expectancy are assumed to be endogenous. The DPD estimator uses lags of the endogenous and pre-determined variables (as well as all of the exogenous variables) as instruments.

There are several statistical tests to evaluate the validity of the instruments including the Sargan, Hansen, and the Difference-in-Hansen tests[26]. Both the Sargan and Hansen statistics test the overidentification restrictions, which are joint tests of model specification and validity of the instruments. The Difference-in-Hansen statistics test the exogeniety of the instruments. In order to evaluate the model specifications in the estimated equations, the results of these tests are reported for each DPD estimation in the table following the regression results.

For each of the four models presented below, the estimated elasticities on Internet use are introduced in a table with a column for each estimation method: Column (1) presents the OLS estimate, (2) is the FMM marginal effects estimate, column (3) is the panel fixed-effects (FE) estimate, and (4) is the DPD estimate. Heteroskedasticity robust standard errors are reported in parenthesis beneath each coefficient. The complete tables of regression results and test statistics for each estimated equation for each model are presented in Appendices D-G.

This chapter is organized into five subsections. Subsection 5.1 discusses the GDP equation, subsection 5.2 presents and discusses the exports equation, subsection 5.3 presents and discusses the market size equations, while subsection 5.4 discusses the HDI equation. The last subsection, 5.5, summarizes the statistical results.

[26]See Roodman (2006) for an excellent treatment of these tests.

5.1 GDP Per Capita (*lgdp*)

This subsection presents estimates of the effects of Internet use on per capita GDP. Figure 2 shows a scatterplot of the relationship between log Internet use and log per capita GDP. Table 2 presents the elasticities of log per capita Internet use on log per capita GDP for the full sample and each of the three subsamples – low, middle, and high income countries – using all four estimators. The full regression results and all of the regression test statistics can be found in Appendix D.

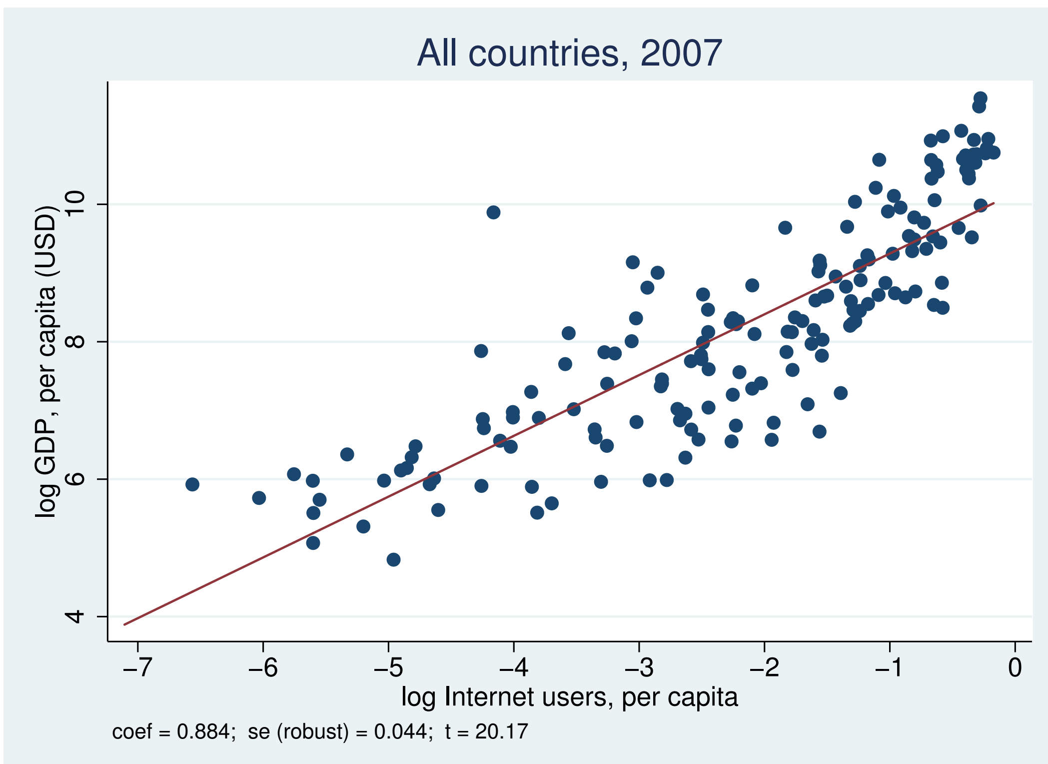

Figure 2: Relationship between Internet use and GDP

The DPD test statistics for the full sample (Table D2) indicate that the model fits the data reasonably well. The Arellano-Bond tests for autocorrelation in the errors show the presence of first order autocorrelation and no second-order autocorrelation as required. Both the Sargan and Hanson tests fail to reject the null hypothesis of valid instrument overidentification restrictions and the Difference-in-Hansen measures fail to reject instrument exogeniety. These tests indicate that the instruments chosen are valid and the model is identified.

Beginning with the estimation on the full sample, the coefficient on Internet use is positive and significant for each estimation method; the estimates differ only in absolute magnitude, as hypothesized. Regardless of the model estimation method, the results consistently show that increasing Internet use significantly has positive effects on per capita GDP. The elasticity on Internet use increases in magnitude between the OLS and FMM estimators and the FE and DPD estimators as the latter methods control for country specific effects, dynamics, and endogeneity. For example, the DPD estimate is 27% larger in absolute magnitude compared to the OLS estimate. It is possible that OLS may be underestimating the effects of Internet use due to endogeneity. As estimated by the DPD method on the full sample, increasing the number of Internet users by 10% increases per capita GPD by 3.2% on average. This confirms the basic premise of this dissertation that increasing Internet use increases development outcomes generally, and GDP per capita specifically.

As we can see in the full regression results of the DPD estimator presented in Table D1, the coefficient on the lagged realization of per capita GDP is positive and significant suggesting the presence of dynamics, which is expected. The elasticity on aid is small and insignificant, but it has a negative sign. This may weakly support the emerging belief that aid does not provide benefits to economic development as measured by per capita GDP. Per capita fixed capital formation has a positive and significant coefficient, again as expected. The effects of secondary schooling is positive while increasing life expectancy appears to have no effect (statistically indistinguishable from zero.)

The estimate of the effects of increasing institutional quality is surprising in that

Table 2: Effects of Internet use on per capita GDP

		(1) OLS	(2) FMM	(3) FE	(4) DPD
		All countries			
(a)	*log per capita Internet users*	0.026***	0.024***	0.035***	0.033***
		(0.005)	(0.004)	(0.009)	(0.009)
		High-income countries			
(b)	*log per capita Internet users*	0.044***		0.073***	0.050
		(0.014)		(0.026)	(0.030)
		Middle-income countries			
(c)	*log per capita Internet users*	0.027***		0.028***	0.034***
		(0.005)		(0.010)	(0.009)
		Low-income countries			
(d)	*log per capita Internet users*	0.026***		0.042**	0.044**
		(0.010)		(0.020)	(0.019)
		Note: *** p<0.01, ** p<0.05, * p<0.1			
		(heteroskedasticity robust standard errors)			

the elasticity is negative and significant. This may suggest that there is a direct cost to providing quality institutions that can be measured by a decrease in per capita GDP. It is also possible that at low levels of development, improved institutions may actually decrease income. Countries may need to reach an institutional threshold before increases in institutional quality increase income. This is an area of current research.[27]

In order to isolate the effects of Internet use from any time or income class effects, I estimate the model with three additional control variables: *time*, *income level* and an interaction term for *time* and *income level* combined. These results are presented in column (5) in Table D1. We can see that the model is robust to the addition of these controls; the coefficient on Internet use remains significant and positive. This

[27]See Karikari and Gyimah-Brempong (2010).

provides additional support to my assertion that there is a causal relationship between Internet use and per capita GDP.

Comparing the results of the OLS, FMM, and FE estimates to the DPD estimates, show that all of the coefficients on the variables in the model have consistent signs and magnitudes. The absolute magnitude and significance of any particular coefficient is, of course, different depending on the estimator. This suggests the model is robust to the various estimation methods.

Although the coefficient estimates of Internet use are qualitatively similar across all estimators, there are quantitate differences. The FMM results closely match the OLS results across samples and in the middle-income estimates, across the other estimators as well, suggesting that the FMM estimation method has captured the average marginal effect across all income levels. The elasticities estimated by the DPD estimator are generally larger in magnitude but with the same sign, precision, and significance as those from the other estimators. The signs of the coefficients of the FE estimates also match the other estimations.

It is possible that the effect of Internet use on income differs according to the level of development. Therefore, I estimate the equations on three subsamples: high, middle and low income countries. The results of these estimations are presented in panels (b)-(d) in Table 2. Panel (b) represents the estimates for high-income countries, panel (c) presents the estimates for middle-income countries, and panel (d) presents the estimates for low-income countries.

To test the hypothesis that the effects of Internet use differ by income class, I create indicator variables for the high and middle income classes and interact these with the measure of Internet use. I then estimate the full sample GDP equation including these interaction terms and find that the the high-income interaction term is significant. This provides confirmation that the Internet effects are not the same across income classes[28].

Reviewing the estimates of Internet use on the three sub-samples in Table 2 (the full results are in Tables D3-D8), we see different magnitudes of the effect for each sub-sample. As expected, the magnitude on the coefficient on Internet use in high-income countries is larger than that of low and middle income countries, but it is not significant unlike in the OLS and FE estimates. This may be due, in part, to the small sample size which is not ideal for the DPD estimator.

Surprisingly, increasing Internet use by 10% in low-income countries, on average, increases per capita GDP by 4.2%, a larger effect than the 3.2% increase in middle-income countries. This may be due to a larger marginal product of Internet use in the lower income countries where surpluses of labor and raw materials exist, but the flow of information necessary to achieve efficient allocations is restricted. Additional Internet use provides the access to information that can allow more efficient allocations. Figure 3 presents a comparison of the DPD estimates of Internet use on per capita GDP for each income class with the statistically insignificant high-income estimate depicted as zero.

While there are no other empirical studies investigating the direct causal effects of Internet use on GDP at the time of writing, the results presented here concurs with the growing literature on the benefits to economic growth from ICT and Internet deployment. Röller and Waverman (2001) study of telecommunication infrastructure in OECD countries find a causal link between the growth rate of ICT infrastructure buildout and the growth rate of aggregate output that supports the results pre-

[28]The coefficient on the high-income class interacted with Internet use is -.0328 with a t-statistic of -2.09 and a p-value of 0.038. The middle-income interaction term is insignificant. Similar results are found for the other three estimation equations presented below, but the results are not reported.

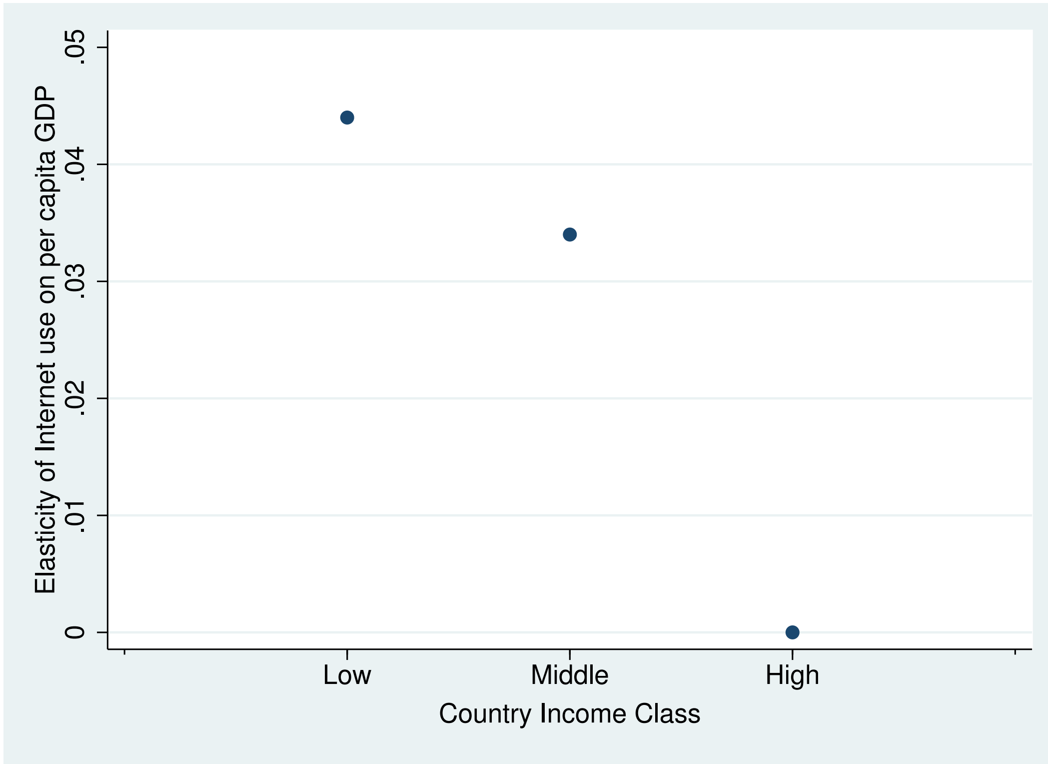

Figure 3: DPD Estimates of Internet use on per capita GDP

sented here. More interestingly, the investigation of broadband Internet penetration in OECD countries by Czernich et al. (2009) finds that on average a 10% increase in broadband Internet access raises per capita GDP growth by 0.9% - 1.5%. While it is difficult to directly compare this estimate to those presented in this dissertation, it is clear that the magnitude and significance of the effects of Internet use on per capita GDP suggest a positive effect.

In sum, these results offer a consistent picture of the positive effects of additional Internet use on per capita GDP regardless of the the income level of the country. The size of the effect differs by the income class of the country as anticipated. This strongly supports the hypothesis of this dissertation. Evaluations of the policy implications of these results are presented in Chapter 6.

5.2 Exports Per Capita (*lexportspc*)

This subsection discusses the estimates of the effects of Internet use on real export revenue in US Dollars. Figure 4 presents the scatter plot of the relationship between Internet use and export revenues for the full sample in 2007. Table 3 presents the estimated elasticities of the log of per capita Internet use on on log per capita export revenue in US Dollars for the full sample and each subsample using all four estimators. The full set of regression results and regression test statistics are presented in Appendix E.

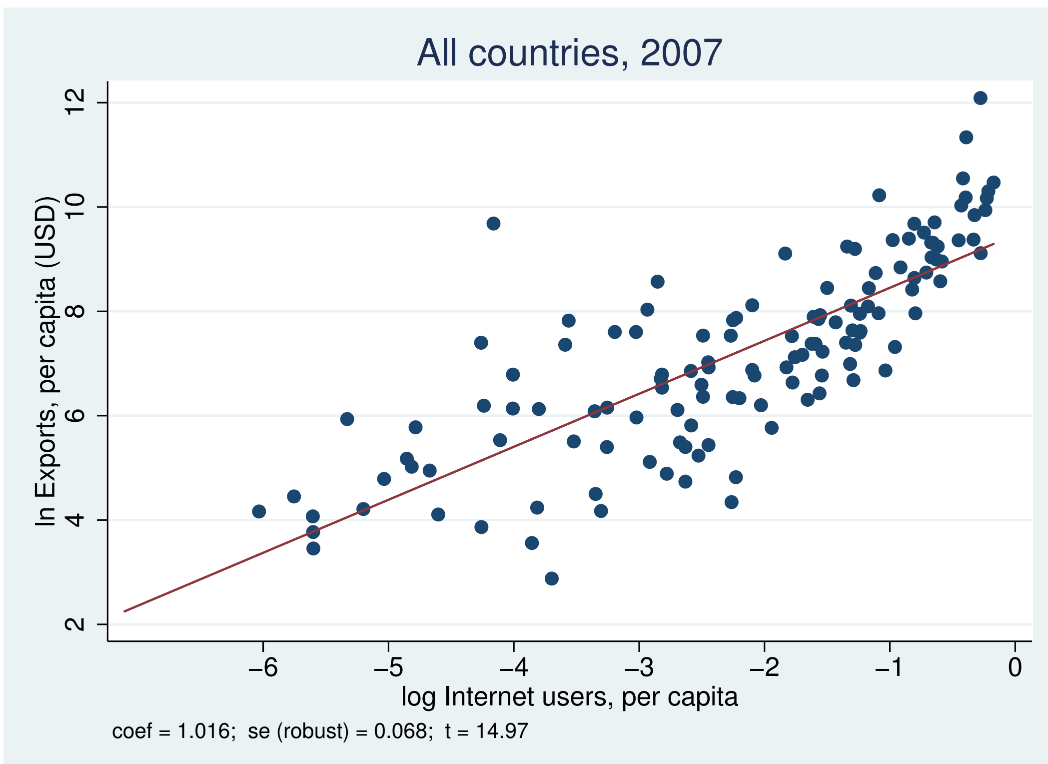

Figure 4: Relationship between Internet use and Exports

Reviewing the DPD test statistics for the full sample estimation presented in Table E2, we can see that the Arellano-Bond tests for autocorrelation in the errors find the necessary first order autocorrelation and the required lack of second order autocorrelation in the error terms. The Sargan, Hansen, and Difference-in-Hansen tests for instrument validity provide evidence that the exogeniety and identification measures all indicate correct specification. These statistical tests suggest that the model fits the data and the instruments are valid.

The estimates, presented in Table 3, on the effects of Internet use on per capita export revenues on the full sample by all four estimation methods are consistently positive. However, most estimates from the sub-samples are generally insignificant while the estimates from the full sample are generally significant. The absolute magnitude and significance are similar for the FMM, FE, and DPD estimates, while the OLS estimates are relatively smaller and insignificant. The elasticity calculated using the DPD estimates for the full sample suggests that, on average, we can expect to see an approximately 2.2% increase in per capita export revenue when Internet use is increased by 10%. These results are consistent with the hypothesis of this dissertation that increasing Internet use has a positive effect on export revenues, but those effects vary depending on the level of a country's economic development.

Table E1 provides the complete regression results from all four estimators for the full sample. We can see that the coefficient on the lagged realization of per capita exports is positive and significant, confirming the assumption that dynamics are present. The elasticity on aid is small, negative, and insignificant. The coefficient on life expectancy is very small and insignificant, but with a negative sign. There is no reason theoretically to expect a significant elasticity on this control. The coefficients on fixed capital formation and secondary education are both positive and significant, as expected. Interestingly, the coefficient on institutional quality is again negative and significant lending additional credence to the thesis mentioned in the previous sub-section regarding the cost of developing institutions.

As in the GDP model, in order to isolate the effects of Internet use from any time

Table 3: Effects of Internet use on per capita Exports

		(1) OLS	(2) FMM	(3) FE	(4) DPD
		All countries			
(a)	*log per capita Internet users*	0.009	0.017***	0.020*	0.023**
		(0.007)	(0.005)	(0.010)	(0.010)
		High-income countries			
(b)	*log per capita Internet users*	0.026		0.054	0.028
		(0.020)		(0.046)	(0.054)
		Middle-income countries			
(c)	*log per capita Internet users*	0.006		0.021	0.026**
		(0.010)		(0.014)	(0.012)
		Low-income countries			
(d)	*log per capita Internet users*	0.009		0.017	-0.007
		(0.013)		(0.018)	(0.022)
		Note: *** p<0.01, ** p<0.05, * p<0.1			
		(heteroskedasticity robust standard errors)			

or income class effects, I estimate the model with three additional control variables: *time*, *income level* and an interaction term for *time* and *income level* combined. These results are presented in column (5) in Table E1. It is clear that the model is robust to the addition of these controls as the coefficient on Internet use remains significant and positive. This estimation adds support to the assertion that there is a causal relationship between Internet use and per capita Exports.

In this dissertation I hypothesize that the effect of Internet use on per capita export revenues differs according to the level of development. Therefore, I estimate the equation using all four estimators on three subsamples: high, middle and low income countries. The results are presented in panels (b)-(d) in Table 3. Panel (b) presents the estimates for high-income countries, panel (c) represents the estimates for middle-income countries, and panel (d) presents the estimates for low-income countries.

Returning to Table 3, we see quite different DPD estimates for the effects of Internet use on exports across income classes. In high-income countries, the elasticity is slightly higher than in middle-income countries, but it is insignificant, while in low-income countries the estimate is negative, but indistinguishable from zero. The DPD estimates for both high and low income sub-samples are somewhat suspect in that the test statistics do not provide the same level of confidence as they do with the full and middle-income samples. Nonetheless, the results from the OLS, FMM, and FE estimators provide sufficient perspective to highlight the observations on the full and middle income samples which are of primary interest.

The most striking result is in middle-income countries where a 10% increase in Internet use is associated with a (statistically significant) 2.5% increase in per capita export revenue. These estimates provide support for the hypothesis of this dissertation, that Internet use will have different effects on the export performance of countries at different levels of development. In Figure 5, we see that additional Internet use does not significantly increase exports for the lowest or highest income countries, but it significantly affects export performance in countries that are identified by middle-income levels.

These results of this dissertation compare favorably with existing research in the literature. Freund and Weinhold (2004) found that increasing Internet hosts by 10% is correlated with a 0.2% increase in total export revenue growth. While it is difficult to make a direct comparison between the estimates, both suggest that increasing Internet use has direct positive effect on exports. In an earlier study, Freund and Weinhold (2002) found that a 10% increase in Internet use abroad is associated with a 1.7% increase in exports of services to the United States. Again, while these estimates

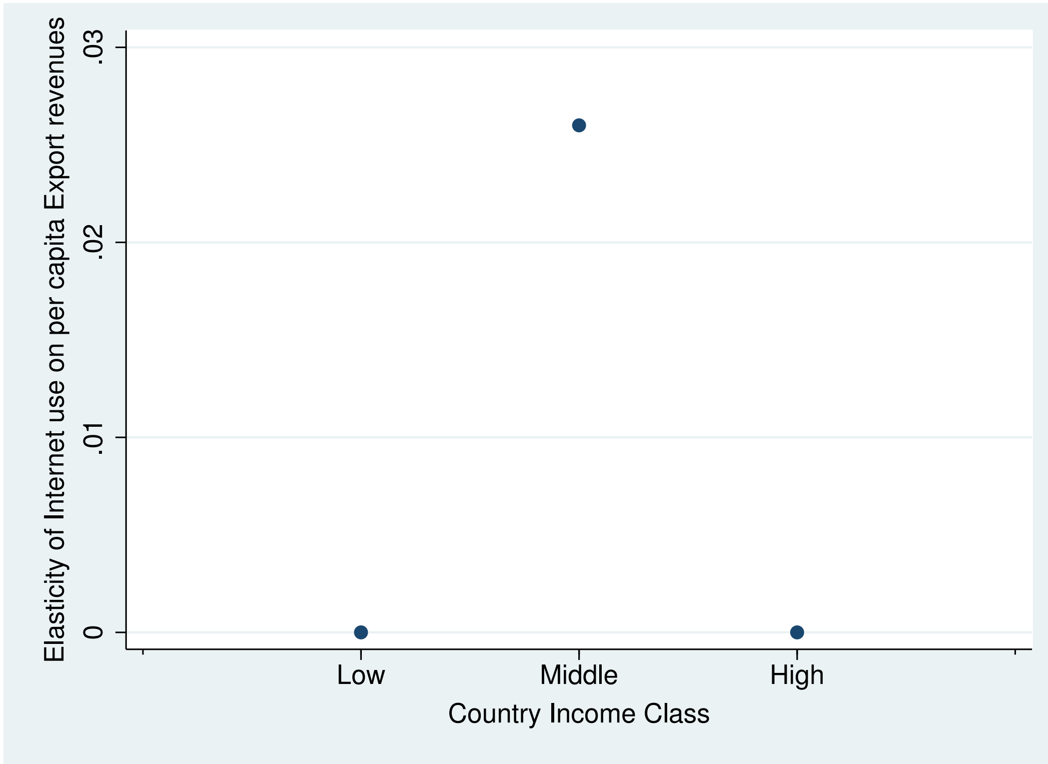

Figure 5: DPD Estimates of Internet use on per capita Exports

cannot be directly compared, the results found in this dissertation support and extend Freund and Weinhold's earlier studies.

The results presented in this dissertation expand upon prior research on exports and Internet use. For example, Clarke and Wallsten's (2006) study concludes that developing countries with higher penetration of Internet access export more to developed countries and Clarke (2008) finds strong correlation between Internet access and exports at the firm level in Eastern Europe and Central Asia. While prior efforts provide specific examples of cases where Internet use has a positive effect on exports, this dissertation provides a more general treatment of the subject of Internet use and exports and comes to similar conclusions.

Summarizing, this dissertation provides evidence that Internet use positively impacts export revenues, all things equal, but the effects vary depending on the economic maturity of the countries being considered. Countries that have moved up from the low level base to a middle level of a Maslow-like developmental hierarchy, as indicated by income class, show significant evidence of positive effects of Internet use on export performance.

5.3 Market Capitalization Per Capita (*lmktcappc*)

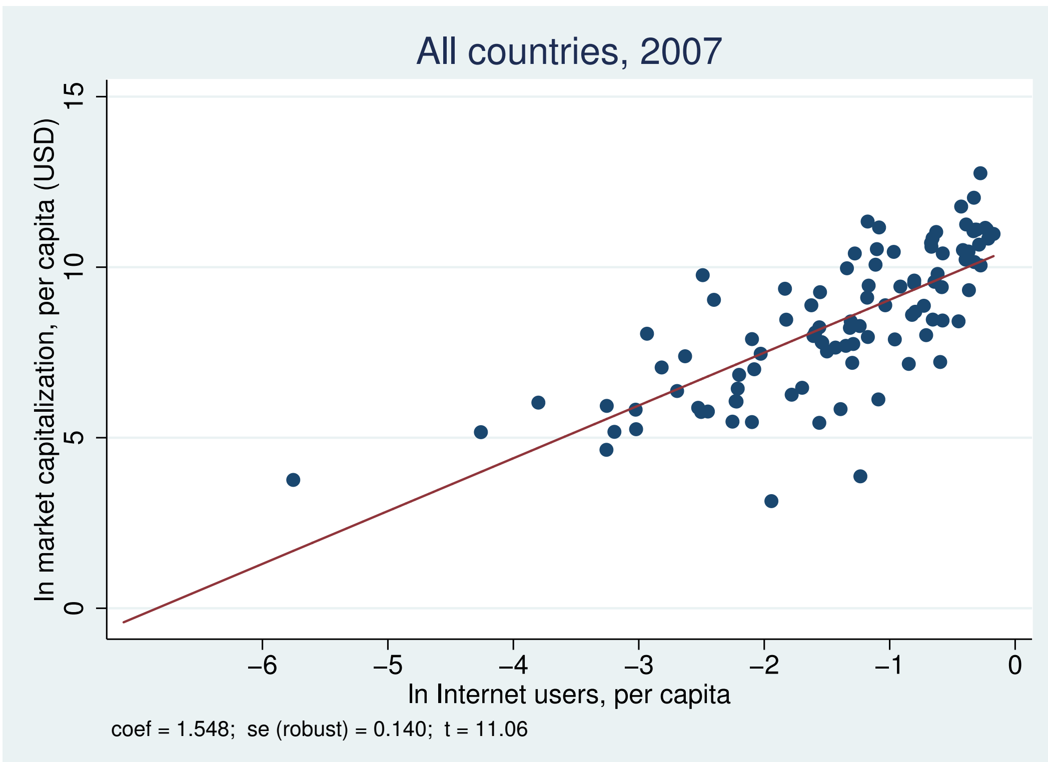

Figure 6: Relationship between Internet use and Market Capitalization

This subsection presents the estimates of the effects of Internet use on the size of domestic equity markets (market capitalization) in US Dollars. Figure 6 displays the scatter plot of the relationship between Internet use and market capitalization for the full sample in 2007. Table 4 presents the elasticities of log per capita export revenue in US Dollars on log per capita GDP for the full sample and each subsample using all four estimators. The full regression results and the regression test statistics can be found in Appendix F.

Reviewing the DPD test statistics for the full sample in Table F2 we see that the Arellano-Bond tests for autocorrelation in the errors finds evidence of the required first order autocorrelation and the absence of send order autocorrelation necessary for accurate estimates. The Sargan, Hansen and Difference-in-Hansen test statistics all fail to reject the hypothesis of valid overidentification restrictions and exogeniety of the instruments. These tests all suggest the model is correctly specified.

Table 4: Effects of Internet use on per capita Market Capitalization

		(1) OLS	**(2) FMM**	**(3) FE**	**(4) DPD**
		All countries			
(a)	*log per capita Internet users*	0.192***	0.193***	0.251***	0.249***
		(0.030)	(0.024)	(0.064)	(0.062)
		High-income countries			
(b)	*log per capita Internet users*	0.244***		0.211**	0.344***
		(0.062)		(0.096)	(0.131)
		Middle-income countries			
(c)	*log per capita Internet users*	0.257***		0.256***	0.331***
		(0.048)		(0.085)	(0.080)
		Low-income countries			
(d)	*log per capita Internet users*	0.138*		0.264*	0.367
		(0.075)		(0.139)	(0.293)
		Note: *** p<0.01, ** p<0.05, * p<0.1			
		(heteroskedasticity robust standard errors)			

Beginning with the full sample estimates by all four estimation techniques presented in Table 4, we find consistent positive and significant elasticities for per capita Internet use on per capita market capitalization. The DPD estimate on the full sample suggests that a 10% increase in Internet use is associated with a 24% rise in per capita market capitalization on average. Figure 7 presents a comparison of the DPD estimates for the three subsamples, with the statistically insignificant estimate for low-income countries represented as zero. This result supports the hypothesis of this dissertation that Internet use has a strong affect on the size of domestic equity markets as measured by per capita market capitalization for countries in the middle and high income classes.

Table F1 provides the complete regression results from the model estimation on the full sample using all four estimators. Regardless of the estimation method, the coefficient on the lagged realization of per capita market capitalization is positive and significant suggesting evidence of dynamics, as expected. As well, the elasticity on Internet use is consistently positive and significant, varying only in magnitude as has been seen in the previous two models. The coefficient on aid is positive (but insignificant) which might suggest that additional aid may be a factor in the development and expansion of domestic capital markets.

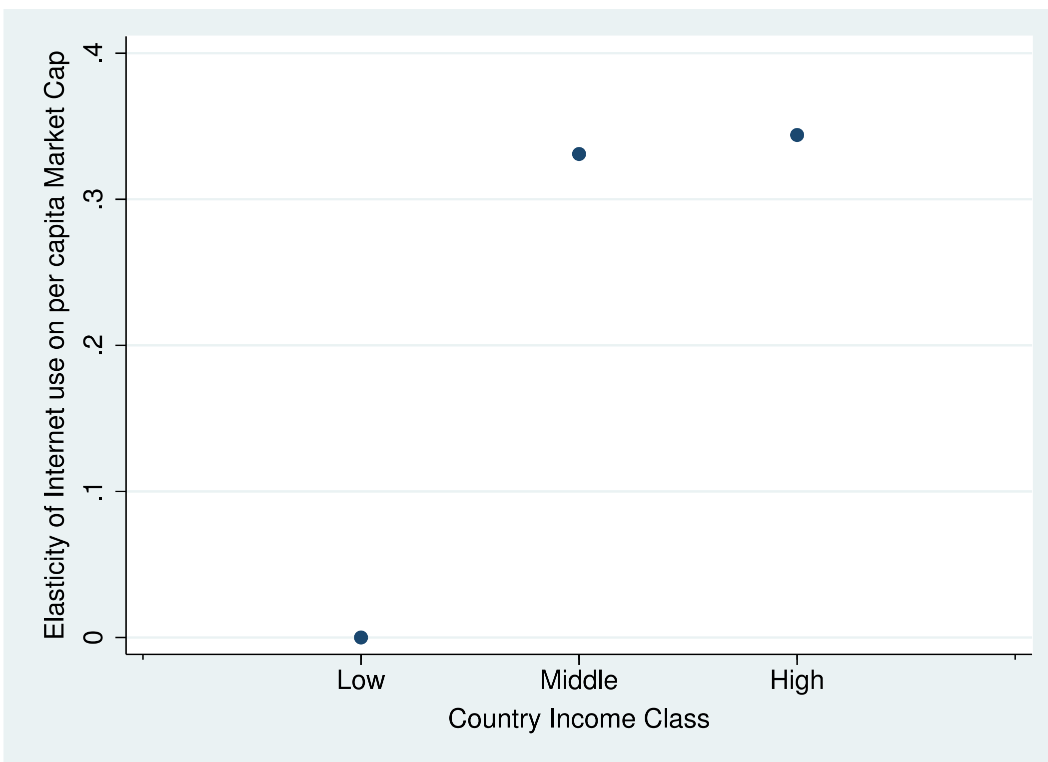

Figure 7: DPD Estimates of Internet use on per capita Market Cap

The elasticity on the health proxy, life expectancy, is very small and an insignificant. The estimates of the effects of capital formation is positive but insignificant potentially suggesting reverse causality, while secondary school education is insignificant and generally positive, but weakly negative (and insignificant) in the DPD estimate. This result may be due in part to the smaller sample size for this investigation. Institutional quality effects are positive but insignificant in the estimators that do not control for endogeneity and dynamics. The DPD estimate shows a very small insignificant negative effect.

As in the GDP and export models I isolate the effects of Internet use from any time or income class effects by estimating the model with three additional control variables: *time*, *income level* and an interaction term for *time* and *income level* combined. These results are presented in column (5) in Table F1. We can see that the coefficient on Internet use remains significant and positive suggesting that the model is robust to the additional of these controls. This provides additional support to my assertion that there is a causal relationship between Internet use and per capita market capitalization.

As in each of the models investigate in this dissertation, I explore the possibility that the effect of Internet use on income differs according to the level of development. Therefore, I again estimate the equations on three subsamples. The results of these estimations are presented in panels (b)-(d) in Table 4. Panel (b) represents the estimates for high-income countries, panel (c) presents the estimates for middle-income countries, and panel (d) presents the estimates for low-income countries.

Moving to the results on the three subsamples in Tables F3-F8, we see positive significant effects of additional Internet use on market capitalization across income classes and estimators, with only the elasticity from the DPD estimator on the low-income country sample statistically insignificant. This is strong evidence of the positive relationship between Internet use and domestic market size that vary across income classes.

It is clear that Internet use has a consistently significant positive effect on equity market size for high and middle income countries, while the effects are insignificant across estimators for low-income countries. The test statistics on the DPD estimates for the high and middle income samples do not provide consistent evidence of correct model specification, most likely due to the relatively small sample sizes. Nonetheless, these estimates, along with the OLS, FMM, and FE estimates, provide reference points for comparison.

There is little published in the literature on the determinants of developing equity markets. Most existing research is focused on either the relationship between capital markets and economic growth[29] or the function of capital markets and the diffusion of technology[30]. The published results clearly show that ICT in general (and the Internet specifically) and capital markets are related and both play a role in economic development. But this dissertation is the only exploration, at the time of publication, of the relationship between increasing Internet use and the size of domestic equity markets as measured by per capita market capitalization.

The results presented in this subsection confirms the hypothesis that Internet use positively impacts domestic market capitalization across income classes, but these effects become significant only for countries in the middle and high income samples. The policy implications of these results are included in Chapter 6.

[29] For example: Levine and Zervos (1996), Bekaert et al. (2001), and Shirai (2004).

[30] See: Chinn and Fairlie (2007) and Yartey (2008).

5.4 UN HDI (*hdi*)

This subsection presents the model which estimates the affects of Internet use on aggregate welfare as measured by the Human Development Index (HDI) a composite measure of education, literacy, and income published by the United Nations Development Programme. Figure 8 is a graphic of the scatterplot relationship between Internet use and the HDI. Table 5 presents the elasticities of Internet use on the HDI for the full sample and each subsample using all four estimators. The full regression results and all of the regression test statistics are presented in Appendix G.

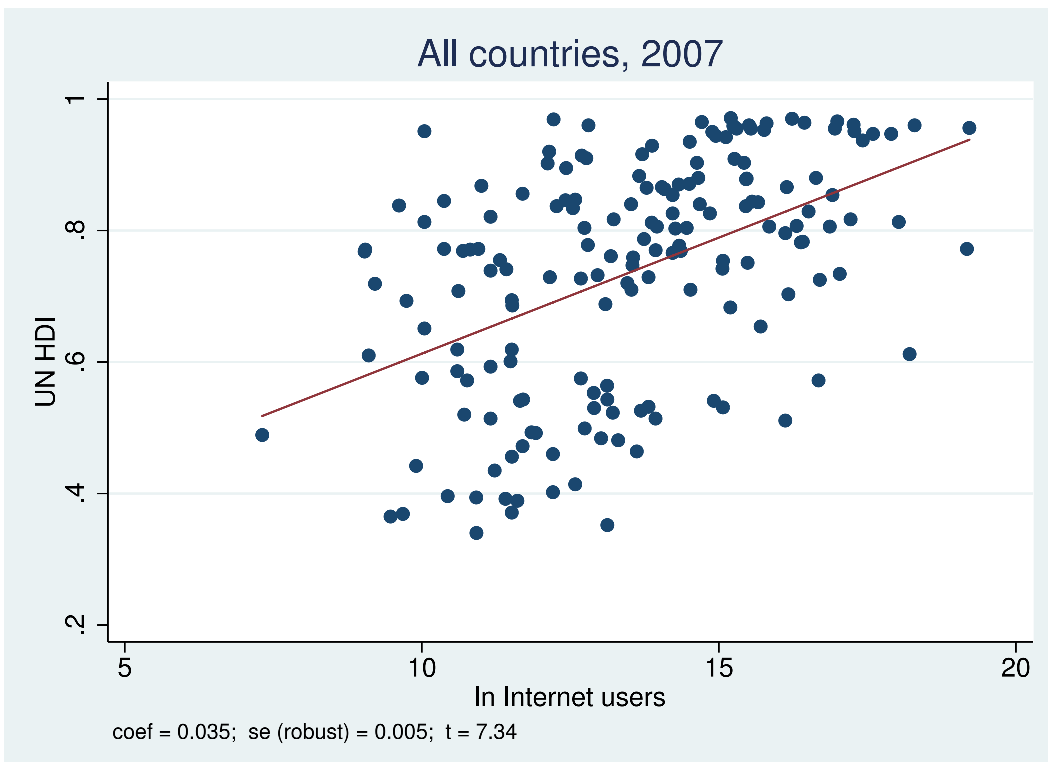

Figure 8: Relationship between Internet use and UN HDI

The test statistics for the DPD estimates on the full sample suggest that the fit is not perfect. The Arellano-Bond test statistics find evidence of first order autocorrelation and the absence of send order autocorrelation, as required, but both the Sargan and Hansen tests reject the valid overidentification restrictions. The Difference-in-Hansen tests are split on the exogeniety of the instruments. Nonetheless, all four estimators show small positive and significant coefficients on Internet use which provides some support to the hypothesis of this dissertation that increasing Internet use increases welfare as measured by the HDI.

The UN HDI is not calculated every year and therefore the sample sizes are significantly reduced when using this indicator as a response variable. In order to expand the observations available for the empirical analysis, cubic spline interpolation and linear extrapolation was employed to provide estimates for the missing observations.

Table 5: Effects of Internet use on HDI

		(1) OLS	**(2) FMM**	**(3) FE**	**(4) DPD**
		All countries			
(a)	*log Internet users*	0.013***	0.013***	0.004***	0.005***
		(0.002)	(0.002)	(0.001)	(0.001)
		High-income countries			
(b)	*log Internet users*	0.012***		0.007***	0.012***
		(0.002)		(0.002)	(0.002)
		Middle-income countries			
(c)	*log Internet users*	0.011***		0.005***	0.006***
		(0.002)		(0.001)	(0.002)
		Low-income countries			
(d)	*log Internet users*	0.016***		0.000	0.007***
		(0.003)		(0.001)	(0.002)
		Note: *** p<0.01, ** p<0.05, * p<0.1			
		(heteroskedasticity robust standard errors)			

For this model, as discussed in Chapter 3, per capita control measures are not used as they may produce biased estimates since there is not sufficient information to accurately measure these covariates in per capita terms. Furthermore, the proxies for health and educational attainment (life expectancy and secondary school duration) are are not included as controls as the index contains measures of these factors. An additional control for the size of the labor force is added since the level measures used are not per capita.

Beginning with the estimates, presented in Table 5, of the effects of Internet use on the HDI for the full sample by the four estimation methods, we see consistent positive significant effects. The elasticity calculated by the DPD estimator for the full sample suggests that, on average, we can expect to see a small, but significant, increase in the HDI when Internet use is increased by 10%. Figure 9 provides a visual comparison of the DPD estimates for each sub-sample. These results provide some evidence to confirm the hypothesis of this dissertation that increasing Internet use has a positive effect on overall welfare as measured by the HDI.

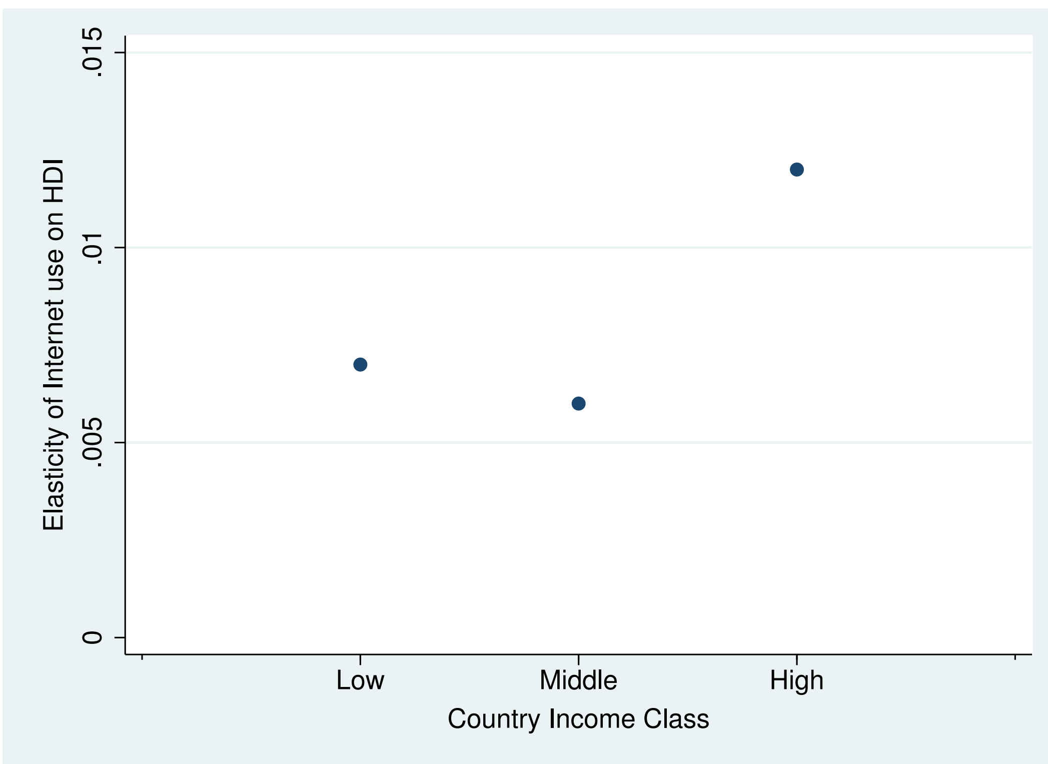

Figure 9: DPD Estimates of Internet use on HDI

Table G1 provides the complete regression results for the full sample. The coefficient on aid is negative and significant. This provides additional support to the hypothesis that aid does not improve overall welfare and is an interesting area of further investigation beyond this dissertation. The coefficient on fixed capital formation is positive and significant, and the estimate on labor force size is negative and significant, both as expected. In this model we see that the estimate of the effects of institutional quality on the HDI is positive and significant on average. This is an interesting counterbalance to the above findings regarding the varying effects of institutional quality on economic development outcomes.

Again I isolate the effects of Internet use from any time or income class effects by estimating the model with three additional control variables: *time*, *income level* and an interaction term for *time* and *income level* combined. These results are presented in column (5) in Table G1. We can see that the coefficient on Internet use remains significant and positive suggesting that the model is robust to the additional of these controls. This provides additional support to my assertion that there is a causal relationship between Internet use and overall welfare as measured by the HDI.

As we have seen in the GDP model, the coefficient on *income level* is significant and negative (increasing income levels corresponds to decreasing income class.) This suggests that there is an income class effect on the HDI.

I continue to explore the possible that the effect of Internet use on income differs according to the level of development by estimating the equations, using all four estimation methods, on the three subsamples: high, middle and low-income countries. The results of these estimations are presented in panels (b)-(d) in Table 2. Panel (b) represents the estimates for high-income countries, panel (c) presents the estimates for middle-income countries, and panel (d) presents the estimates for low-income countries.

The results of the estimates of Internet use on the HDI for each of the subsamples, presented in tables G3-G8 show consistent small, positive, and significant effects. The estimated effects are larger for high-income countries and the effects for low and middle income countries are nearly the same. These results add evidence in support of the conclusion of this dissertation that Internet use has a significant positive effect on economic development.

There are no published works in the literature on the welfare effects of ICT and the Internet in developing countries; therefore there are no empirical investigations with which to compare the results found in this dissertation. That being said, there are studies that suggest there is a welfare effect from adding additional Internet users.

Crandall and Jackson (2001) and Prahalad and Hammond (2002) describe the potential for firms to benefit from the expansion of ICT infrastructure in underdeveloped countries. Jensen's study detailing the welfare enhancing impact of cellular phone on rural fisherman in India (2007) provides evidence to support the hypothesis that technology can improve welfare even in underdeveloped areas. Thompson and Garbacz (2007) find that poor countries benefit from expanding information networks. Aker and Mbiti (2010) reason that increasing access to mobile phones in the low-income countries in Africa has great potential for welfare enhancement, but their investigation does not provide empirical support.

This subsection presents my initial attempt to investigate the effects of Internet us on economic welfare. While estimation models using aggregate measures on an index itself composed of aggregates is difficult, this investigation does succeed in providing some additional evidence in support of the hypothesis of this dissertation that additional Internet use positively impacts economic development.

5.5 Concluding Observations

Looking across all of the models and estimation results, there is evidence of support for the hypothesis of this dissertation that additional Internet use has positive effects on economic development as measured by GDP, exports, market size, and the UN HDI. Results across the full sample of countries often show significant positive effects, but when the estimates are run on stratified groups of countries – high, middle and low-income countries as distinct subsamples – it is apparent that the effects of additional Internet users varies in absolute magnitude and significance across income classes.

My original hypothesis was that additional Internet users would have little effect on low-income countries. The results of the model applied to per capita GDP produced a surprising result. While the elasticity on the full sample estimate closely matched the estimate for the middle-income sample as expected, the elasticity on the low-income sample was positive and slightly larger. This unexpected result suggests that additional Internet use has an impact on per capita income even in the least developed countries.

The results of the model on per capita export revenue provided estimates that matched my expectations that middle-income countries would show the greatest gains from additional Internet use. Again, the elasticity estimated for the full sample was close to the estimate on the middle-income sample. The elasticities on Internet use for low and high income countries were insignificant, but the elasticity was positive and significant for middle-income countries.

As there has been little published on the determinants of market size in developing countries, my only expectation for the effects of internet use on market size was that lower income countries would likely show no effect, as newly created markets may not be integrated into the global financial system. The results confirmed this as the middle and high income country have significant positive elasticities, while the low-income country elasticity was insignificant. The high-income country elasticity on Internet use was even greater than the the estimate for middle-income countries. This may suggest that as wealth increases and countries move to higher income levels, additional Internet access provides additional access to domestic capital markets, which provides opportunities for additional investment.

The model estimates from the exploration of Internet use on the UN HDI are unexpected. Although I am less confident of the model fit in this case, the results indicate that there may be interesting effects that warrant further exploration. As in the other models, the elasticity estimate on the full sample was close to that of the middle-income sample and both were positive and significant. This matched my general expectations for this investigation.

Surprisingly, the elasticity estimated on the low-income sample was positive and significant. As the HDI is an aggregate measure that includes per capita GDP, it is reassuring in a way that this result is supported by the findings in the model discussed above on the effects of Internet use on GDP. Additionally, as the UN also includes literacy rates and life expectancy[31] in the calculation of the HDI, perhaps additional Internet use provides access to education and health care information in low-income countries that have a positive effect. This is an interesting area for future research.

The results of these four models of Internet use on four different economic development outcomes, applied to the full sample of countries and each of the three subsamples stratified by income class, and estimated by four different econometric techniques provide a rich framework for understanding the effects of Internet use on

[31] The UN HDI changed the components beginning in 2010, but this dissertation uses UN HDI measurements only up to 2007.

economic development outcomes.

It is difficult to ignore the clear difference in the magnitude and significance of the effects depending on the income class and the evidence of significant positive effects of additional Internet users on all four economic outcomes for middle-income countries. These results confirm the research hypothesis of this dissertation that Internet use is an important positive determinant of economic development, but these effects vary depending on where a country falls in a Maslow-like economic developmental hierarchy stratified by income level.

6 Policy Implications and Future Research

6.1 Dissertation Summary

This dissertation investigates the effects of Internet use on economic development. The hypothesis explored is that increasing Internet use positively affects a range of development outcomes including per capita GDP, per capita export revenue for goods and services, the per capita size of domestic equity markets, and overall welfare as measured by the UN Human Development Index. However, Internet use affects economies differently depending on the income level of the country.

I consider an economic hierarchy of needs (drawing on Maslow's influential work on human psychology) where, at each level of development, Internet use will have a measurably different impact. At the lowest level of development where the population struggles to survive due to extreme poverty, missing or failing public health institutions, ongoing violent conflict or generally unstable political systems, it is unlikely that Internet would be available, and if it was, people could use it to improve their situations.

Countries that have achieved some economic development success (and have moved into the middle-income class) will likely have functioning institutions and the infrastructure necessary to support widespread Internet use. I expect to find the largest impact of Internet use on economic development outcomes in this class of countries. In the most developed countries, the marginal effect of additional Internet use may not produce measurable effects.

In order to conduct this empirical investigation, a panel data set was constructed from three main data sources: the World Bank World Development Indicators and World Governance Indicators (WGI), the International Telecommunications Union World Telecommunication ICT Indicators, and the United Nations Human Development Index. These data were collected and combined to create a panel of economic measures on 202 countries over an eleven-year period spanning 1996 to 2007. The effectiveness of Internet use is tested using four econometric techniques (Ordinary Least Squares, Finite Mixture Modeling, and Dynamic Panel Data) on each sample and the results are compared to explore the effects of additional Internet use at different developmental stages.

The econometric investigation uses a production function framework, with Internet use as an additional input, for each of the four economic outcomes: per capita GDP, per capita export revenue, per capita equity market capitalization, and the UN HDI. The primary controls for this framework are drawn from across the academic literature: per capita fixed capital formation, per capita net foreign aid, secondary school duration in years, life expectancy at birth in years, and a measure of institutional quality for the WGI. The variables selected as controls are those commonly used in growth and development empirics as proxies for the critical components of economic development: fixed capital formation, foreign aid, education, health, and institutions. There is no control for labor, as these models are estimating per capita outcomes.

Four different econometric estimation techniques are used on each of the four samples for the four outcomes. Ordinary Least Squares (OLS) is used as the baseline estimation method, but in the presence of endogeneity and dynamics, this estimator will produce biased and inconsistent results. As such, Finite Mixture Modeling (FMM) and Dynamic Panel Data (DPD) estimators are also used.

The FMM estimation method models a different distribution for each class and, while it does not directly address endogeneity and dynamics problems, it can model the different elasticities across income classes. The DPD General Method of Moments (GMM) estimators, are commonly used in the literature to estimate models on cross-country data when dynamics and endogeneity are present. These estimators are preferred for three reasons. First, it is important to capture the persistent effects of Internet use in a dynamic framework. Second, there are important endogeneity concerns with respect to Internet use, economic aid, and the measures of development outcomes under consideration. Without well identified and understood instrumental variables, two-stage least squares techniques are unavailable. And third, it is important to control for unobserved country heterogeneity that may be correlated with the investigated outcomes.

Looking across all of the models and estimation results, there is evidence of support for the hypothesis of this dissertation that additional Internet use has positive effects on economic development as measured by GDP, exports, market size, and the UN HDI welfare index. Results across the full sample of countries often show significant positive effects, but when the estimates are run on stratified groups of countries – high, middle and low income countries as distinct subsamples – the effects of additional Internet users varies in absolute magnitude and significance across income classes.

The results of the estimation of the effects of Internet use on per capita GDP produced a surprising result. While the elasticity on the full sample estimate closely matched the estimate for the middle-income sample as expected, the elasticity on the low-income sample was positive and slightly larger. This suggests that additional

Internet use has a positive impact on per capita income even in the least developed countries. The mechanism through which this takes place is worth exploring in future research.

The results of the model on per capita export revenue provided estimates that matched my expectations that middle-income countries would show the greatest gains from additional Internet use. Again, the elasticity estimated for the full sample was close to the estimate on the middle-income sample. The elasticities on low and high income countries were insignificant, but the elasticity was positive and significant for middle-income countries.

The effects of Internet use on market size shows that in lower income countries there is no effect. But, the results indicate that middle and high income countries have significant positive elasticities on Internet use. The high-income country elasticity was even greater than the the estimate for middle-income countries. This may suggest that as wealth increases and countries move to higher income levels, increasing Internet access provides additional access to domestic capital markets, which generates additional investment opportunities.

The model estimates from the exploration of Internet use on the UN HDI are unexpected. Although the model fit is not as good as in the prior three models, the results indicate that there may be interesting effects that warrant further exploration. As seen in the three other estimations, the elasticity estimate on the full sample was close to that of the middle-income sample and both were positive and significant. Surprisingly, the elasticity estimated on the low-income sample was positive and significant. Since the HDI is an aggregate measure that includes per capita GDP, this result is supported by the findings from the estimation of Internet use on GDP.

Where prior studies have investigated the impact of Internet use on similar economic outcomes, the results in this dissertation support prior findings. Of particular interest, the positive and significant effects of Internet use on per capita GDP concords with the results of Czernich et al. (2009) which show a similar effect of Broadband Internet on GDP growth in OECD countries. In addition, the results in this dissertation showing the impact of Internet on export revenues supports the findings in Freund and Weinhold's studies of the effects of Broadband Internet on exports.

It is important to note that the estimates of Internet use are robust to the various specifications and estimation methods. For each sample and specification, the estimates of the impact of Internet use are consistent regardless of the particular estimation method.

6.2 Policy Implications

Given that Internet use affects economic development differently depending on the income level of the country and the specific outcome, the policy recommendations derived from these results vary according to the country's income level.

In low-income countries on average, additional Internet use has a significant positive effect on per capita GDP and on overall welfare as measured by the HDI. This suggests that policy initiatives should focus on providing additional Internet access, likely deployed on new or existing cellular phone infrastructure, in order to enhance job creation, health care services, and programs to increase literacy. Importantly, since I have shown that ICT and Internet use have positive development effects, the opportunity to leverage aid and FDI to help leap-frog outdated technologies and immediately deploy new technological infrastructure, such as wireless telephone and Internet, can enhance development efforts in LDCs.

Institutions are necessary to deliver and manage these services, but we have seen that there may be an initial cost to creating functioning institutions in some countries. Policy makers can direct foreign investment and domestic capital deployment toward developing the Internet infrastructure while encouraging foreign aid to address health and education programs, for example. There were no significant effects on additional Internet use on exports or market size in low-income countries. As such, policy makers should avoid Internet-based development programs targeted at developing exports or capital markets until the economy has achieved higher levels of income.

Internet use boosts economic and societal well-being measures most significantly in countries that have achieved middle-income status. The results presented in this dissertation suggest that increasing Internet use has a positive and significant effect on all four measures of economic development in these countries. This suggests that policy makers in countries that have begun to emerge from the lowest level of economic development should encourage widespread deployment of Internet access. Policy makers must provide the necessary institutional and legal support in order for the service sector to provide mobile banking, insurance, and other Internet enabled technological solutions to the population.

6.3 Future Research

This dissertation has attempted to provide a broad base for research into the effects on Internet use on economic development. The results show clear evidence of the significant positive effects that vary according to the level of development achieved. Nonetheless, as in any emerging research area, this dissertation has left out a number of interesting and important research questions and areas worth exploring.

Although I have found evidence of the effects of Internet use on several development outcomes, I do not explore the determinants of Internet use. What impedes or advances Internet use? How do the economic, institutional, and political circumstances of particular counties alter, not just the availability of access to the Internet, but the actual likelihood of Internet use? Another interesting question is the exact transmission mechanism. What are the mechanisms through which Internet use actually affect these outcomes?

This investigation has opened new areas of research that build upon on the results found. Future investigations into the effects of Internet use in developing countries will benefit from the additional data that becomes available on the years beyond 2007. As the Internet is delivered to developing economies through fiber optic backbones that transit specific borders, spatial econometric techniques, involving contiguity measures based on data and voice transmission networks, may provide an additional way to investigate the effects of Internet use on economic development.

There is an interesting growth story in the results found of the effects of Internet use on per capita GDP. A future paper may investigate this relationship from a more traditional macroeconomic growth modeling perspective.

Technology is bringing heath care services to remote areas. "In rural Kenya, telemedicine allows inexperienced doctors to liaise with specialist consultants many hundreds of miles away" (Independent News and Media 2010). These results may suggest that Internet access may more directly affect specific health and education outcomes in developing countries. The evidence of Internet use on the UN HDI suggests that there may be a direct effect of Internet use on educational and health outcomes directly.

Technology deployments in developing countries will necessarily be in stages, not all at once across an entire country. Exploring the effects of Internet use may be well suited to the use of randomized controlled trials, or random evaluations, in field experiments. Providing access to the Internet as a treatment is not burdened by the same ethical problems as health or education treatments. In addition, as data becomes available from developing countries, it will be fascinating to explore these models on firm-level data. Perhaps answers to some of the unanswered questions of transmission mechanisms or likelihood of Internet use can be discovered in country-level data.

The field of research in economic development is rapidly becoming the most interesting place to explore the effects of technology on emerging economies. This dissertation is my modest attempt to advance the field by providing comprehensive empirical evidence of the clear economic benefits to increasing Internet use in developing countries.

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Appendices

Appendix A: World Bank 2007 Country Income Classification

High Income: OECD Member Countries (27)[32]

Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom, United States

High Income: non-OECD Countries (34)[33]

Andorra, Antigua and Barbuda, Aruba, Bahamas, Bahrain, Barbados, Bermuda, Brunei, Cayman Islands, Channel Islands, Croatia, Cyprus, Equatorial Guinea, Estonia, Faeroe Islands, French Polynesia, Guam, Isle of Man, Israel, Kuwait, Liechtenstein, Malta, Monaco, Netherlands Antilles, New Caledonia, Northern Mariana Islands, Oman, Qatar, San Marino, Saudi Arabia, Singapore, Slovenia, Trinidad and Tobago, United Arab Emirates

Upper Middle Income Countries (45)[34]

Algeria, Argentina, Belarus, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Fiji, Gabon, Grenada, Jamaica, Kazakhstan, Latvia, Lebanon, Libya, Lithuania, Macedonia, Malaysia, Mauritius, Mexico, Montenegro, Namibia, Panama, Peru, Poland, Romania, Russian Federation, Serbia, Seychelles, South Africa, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Turkey, Uruguay, Venezuela

[32] Members of high-income sample (*income code = 1, income level = 1*).

[33] Members of high-income sample (*income code = 2, income level = 1*).

[34] Members of middle-income sample (*income code = 3, income level = 2*).

Appendix A: World Bank 2007 Income Classification (Continued)

Lower Middle Income Countries (53)[35]

Albania, Angola, Armenia, Azerbaijan, Belize, Bhutan, Bolivia, Cameroon, Cape Verde, China, Congo (Rep), Cote d'Ivoire, Djibouti, Ecuador, Egypt, El Salvador, Georgia, Guatemala, Guyana, Honduras, India, Indonesia, Iran, Iraq, Jordan, Kiribati, Lesotho, Maldives, Marshall Islands, Micronesia, Moldova, Mongolia, Morocco, Nicaragua, Nigeria, Pakistan, Papua New Guinea, Paraguay, Philippines, Samoa, Sao Tome and Principe, Solomon Islands, Sri Lanka, Sudan, Swaziland, Syria, Thailand, Timor-Leste, Tonga, Tunisia, Turkmenistan, Ukraine, Vanuatu

Low Income Countries (43)[36]

Afghanistan, Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Congo (Dem. Rep.), Eritrea, Ethiopia, Gambia, Ghana, Guinea, Guinea-Bissau, Haiti, Kenya, Democratic Republic of Korea, Kyrgyz Republic, Lao PDR, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, Senegal, Sierra Leone, Somalia, Tajikistan, Tanzania, Togo, Uganda, Uzbekistan, Vietnam, Yemen, Zambia, Zimbabwe

[35] Members of middle-income sample (*income code = 4, income level = 2*).

[36] Members of low-income sample (*income code = 5, income level = 3*).

Appendix B: Descriptive Statistics

Table B1: Descriptive statistics, all countries, 1996-2007

	Obs	**Mean**	**Std. Dev.**	**Min**	**Max**
log Internet users, per capita	2178	-3.83	2.52	-13.74	-0.15
log Internet users, total	2219	11.57	3.00	2.94	19.22
log GDP per capita (USD)	2193	7.81	1.63	4.35	11.54
log Exports, per capita (USD)	2031	6.67	1.91	1.74	12.09
log Market Cap, per capita (USD)	1250	7.05	2.59	-1.79	12.75
UN HDI	978	0.72	0.18	0.26	0.97
UN HDI (interpolated and extrapolated)	2148	0.71	0.18	0.19	0.97
log Net aid, per capita (USD)	1867	3.34	1.61	-2.70	8.48
log Net aid, total (USD)	1897	18.68	1.70	9.90	23.82
log Fixed capital formation, per capita (USD)	1953	6.19	1.71	0.99	10.02
log Fixed capital formation, total (USD)	1982	21.91	2.36	16.69	28.58
Life expectancy at birth (years)	1424	68.83	10.00	38.57	82.51
Secondary education, duration (years)	1923	6.31	0.93	4	9
Log labor force, total	2129	14.84	1.87	10.44	20.48
Institutional quality index	1654	-0.05	0.95	-2.55	2.03
World Bank income category	2424	3.25	1.32	1	5

Appendix B: Descriptive Statistics (Continued)

Table B2: Descriptive statistics, high-income countries, 1996-2007

	Obs	**Mean**	**Std. Dev.**	**Min**	**Max**
log Internet users, per capita	632	-1.78	1.40	-8.24	-0.15
log Internet users, total	653	12.98	2.84	5.30	19.22
log GDP per capita (USD)	598	9.87	0.72	6.32	11.54
log Exports, per capita (USD)	528	9.00	0.85	6.06	12.09
log Market Cap, per capita (USD)	508	9.35	1.34	5.19	12.75
UN HDI	258	0.91	0.05	0.66	0.97
UN HDI (interpolated and extrapolated)	564	0.90	0.06	0.60	0.97
log Net aid, per capita (USD)	247	3.12	2.20	-2.70	7.74
log Net aid, total (USD)	251	16.86	2.26	9.90	21.52
log Fixed capital formation, per capita (USD)	521	8.30	0.66	6.45	10.02
log Fixed capital formation, total (USD)	526	23.79	2.07	19.07	28.58
Life expectancy at birth (years)	514	76.85	4.07	48.69	82.51
Secondary education, duration (years)	539	6.50	1.04	4	9
log Labor force, total	588	14.48	1.93	11.13	18.87
Institutional quality index	459	1.09	0.62	-1.23	2.03
World Bank income category	732	1.56	0.50	1	2

Appendix B: Descriptive Statistics (Continued)

Table B3: Descriptive statistics, middle-income countries, 1996-2007

	Obs	**Mean**	**Std. Dev.**	**Min**	**Max**
log Internet users, per capita	1079	-3.94	2.04	-11.77	-0.58
log Internet users, total	1092	11.46	2.90	2.94	19.17
log GDP per capita (USD)	1129	7.57	0.82	5.60	9.44
log Exports, per capita (USD)	1049	6.55	1.02	2.96	9.36
log Market Cap, per capita (USD)	627	5.90	1.71	-1.42	9.77
UN HDI	500	0.73	0.10	0.43	0.88
UN HDI (interpolated and extrapolated)	1104	0.72	0.10	0.42	0.88
log Net aid, per capita (USD)	1116	3.39	1.72	-2.36	8.48
log Net aid, total (USD)	1130	18.69	1.48	11.29	23.82
log Fixed capital formation, per capita (USD)	998	6.05	0.89	3.47	8.35
log Fixed capital formation, total (USD)	1008	21.70	2.14	16.69	28.01
Life expectancy at birth (years)	650	68.02	7.25	42.56	78.79
Secondary education, duration (years)	956	6.20	0.95	4	8
log Labor force, total	1037	14.80	2.05	10.44	20.48
Institutional quality index	817	-0.30	0.60	-2.09	1.28
World Bank income category	1176	3.54	0.50	3	4

Appendix B: Descriptive Statistics (Continued)

Table B4: Descriptive statistics, low-income countries, 1996-2007

	Obs	Mean	Std. Dev.	Min	Max
log Internet users, per capita	467	-6.36	2.32	-13.74	-1.56
log Internet users, total	474	9.86	2.46	3.91	16.70
log GDP per capita (USD)	466	5.73	0.50	4.35	7.47
log Exports, per capita (USD)	454	4.23	0.85	1.74	6.43
log Market Cap, per capita (USD)	115	3.14	1.75	-1.79	7.66
UN HDI	220	0.48	0.11	0.26	0.73
UN HDI (interpolated and extrapolated)	480	0.46	0.11	0.19	0.73
log Net aid, per capita (USD)	504	3.33	0.85	-0.12	5.26
log Net aid, total (USD)	516	19.55	1.02	16.74	22.41
log Fixed capital formation, per capita (USD)	434	3.99	0.78	0.99	5.70
log Fixed capital formation, total (USD)	448	20.18	1.43	16.79	24.08
Life expectancy at birth (years)	260	55.02	7.99	38.57	74.22
Secondary education, duration (years)	428	6.34	0.64	5	7
log Labor force, total	504	15.32	1.15	12.25	18.14
Institutional quality index	378	-0.90	0.52	-2.55	0.03
World Bank income category	516	5.00	0.00	5	5

Appendix C: Variable Distributions

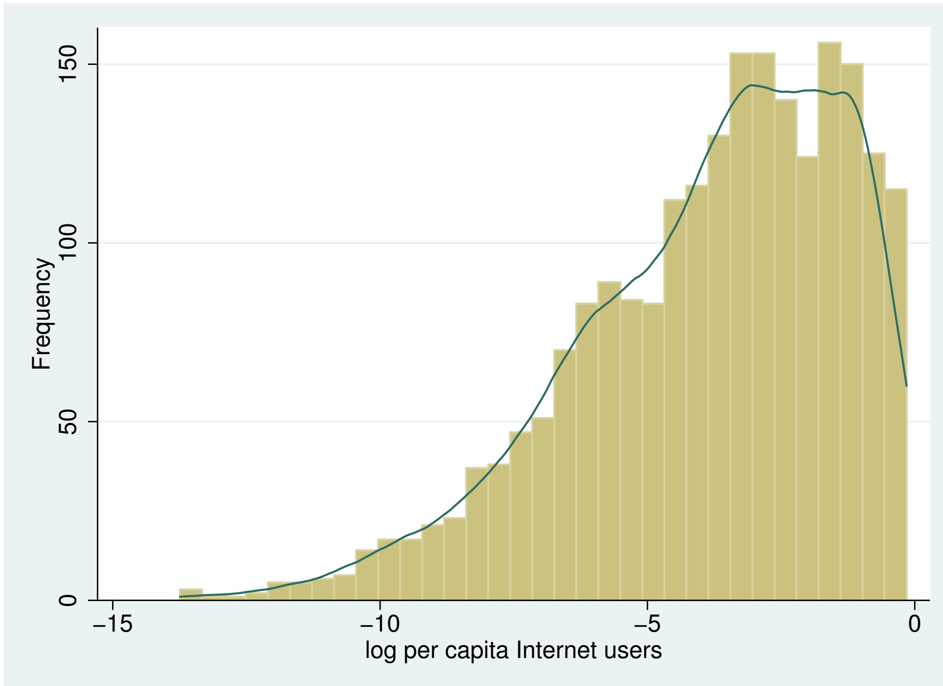

Figure C1: Histogram, *log Internet users per capita*, All countries 1996-2007

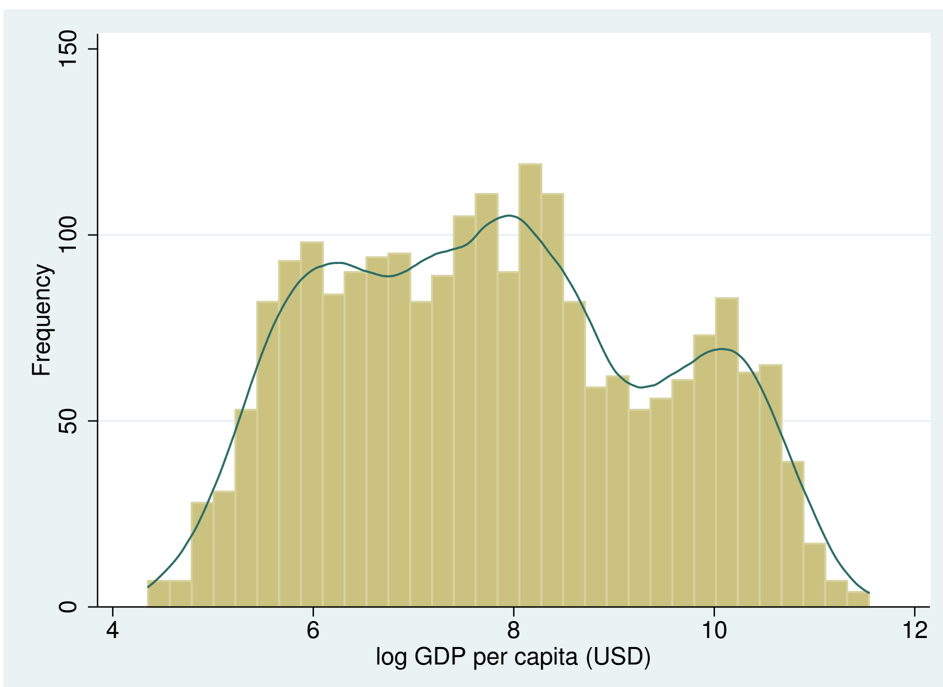

Figure C2: Histogram, *log GDP per capita*, All countries 1996-2007

Appendix C: Variable Distributions (Continued)

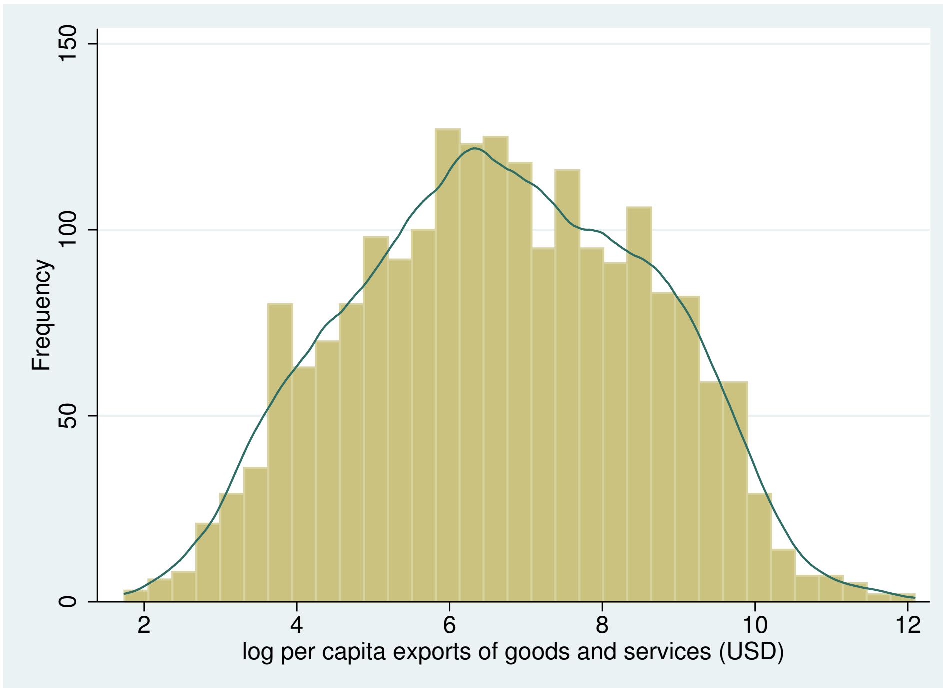

Figure C3: Histogram, *log exports per capita*, All countries 1996-2007

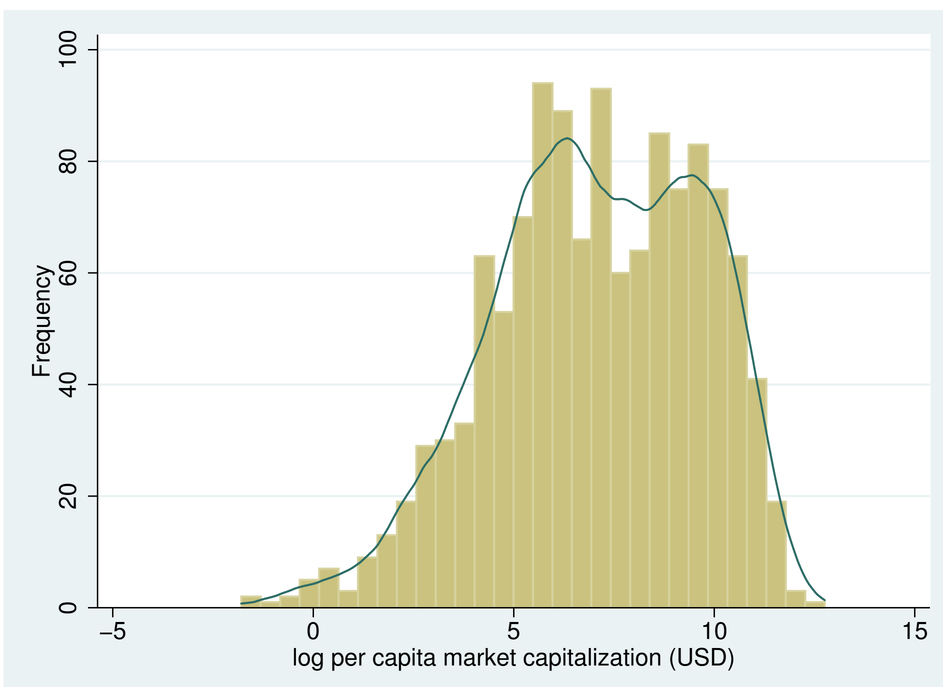

Figure C4: Histogram, *log market cap per capita*, All countries 1996-2007

Appendix C: Variable Distributions (Continued)

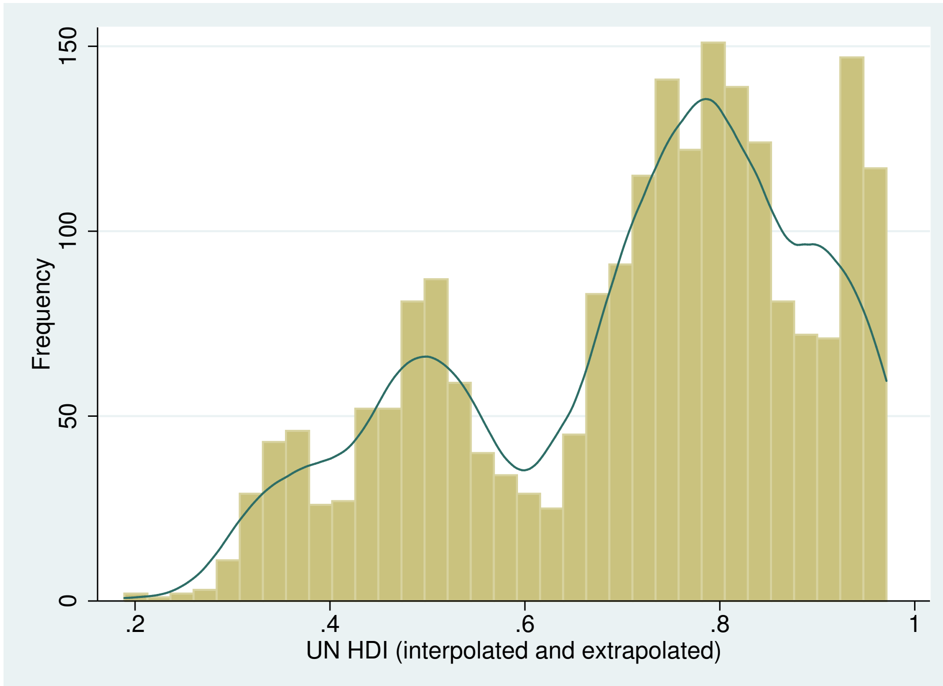

Figure C5: Histogram, *hdi*, All countries 1996-2007

Appendix D: GDP Regression Results

Table D1: Results: *log per capita GDP* (all countries)

	(1) OLS	(2) FMM	(3) FE	(4) DPD	(5) DPD
Lag(1) log GDP per capita	0.839***	0.859***	0.682***	0.795***	0.844***
	(0.022)	(0.013)	(0.056)	(0.048)	(0.049)
log per capita Internet users†	0.026***	0.024***	0.035***	0.033***	0.037**
	(0.005)	(0.004)	(0.009)	(0.009)	(0.014)
log per capita aid (USD)†	-0.003	-0.005*	-0.004	0.002	-0.001
	(0.003)	(0.003)	(0.012)	(0.011)	(0.010)
Life expectancy at birth†	-0.003***	-0.002***	-0.007	0.000	-0.003
	(0.001)	(0.001)	(0.007)	(0.003)	(0.003)
log per capita fixed cap (USD)	0.165***	0.151***	0.277***	0.188***	0.134***
	(0.019)	(0.013)	(0.043)	(0.041)	(0.037)
Secondary education (years)	0.020***	0.020***	0.007	0.017**	0.017**
	(0.004)	(0.004)	(0.024)	(0.007)	(0.007)
Institutional quality (WGI)	-0.051***	-0.054***	-0.036	-0.055***	-0.053***
	(0.010)	(0.008)	(0.037)	(0.014)	(0.015)
Time					-0.006
					(0.010)
Income level					-0.087**
					(0.037)
Time x Income level‡					0.004
					(0.004)
Constant	0.424***		1.337***	0.478***	0.825***
	(0.083)		(0.504)	(0.172)	(0.270)
Number of observations	634	634	634	634	634
Adjusted R^2	0.993		0.924		
Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)					
†Endogenous in DPD estimation; ‡Interaction term					

Appendix D: GDP Regression Results (Continued)

Table D2: Test statistics *log per capita GDP* (all countries)

Test	**Statistic**	**p-value**	**Result**	H_0 **(Null Hypothesis)**
Hausman	$\chi^2(7) = 80.69$	0.000	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 6.29$	0.006	Reject	RE present
Arellano-Bond AR(1)	$z = 3.11$	0.002	Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = 1.74$	0.082	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(146) = 149.10$	0.962	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(146) = 107.87$	0.992	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(24) = 12.17$	0.978	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = 1.91$	0.590	Fail to Reject	Exogenous instruments

Note: DPD test statistics for equation (4) in Table D1

Appendix D: GDP Regression Results (Continued)

Table D3: Results: *log per capita GDP* (high-income countries)

	(1) OLS	**(2) FE**	**(3) DPD**
Lag(1) log GDP per capita (USD)	0.924***	0.650***	0.903***
	(0.047)	(0.060)	(0.140)
log per capita Internet users†	0.044***	0.073***	0.050
	(0.014)	(0.026)	(0.030)
log per capita aid (USD)†	-0.015*	-0.028	-0.028
	(0.009)	(0.030)	(0.030)
Life expectancy at birth†	-0.006*	-0.001	0.001
	(0.003)	(0.033)	(0.019)
log per capita fixed capital formation (USD)	0.063	0.272***	0.102
	(0.048)	(0.080)	(0.099)
Secondary education, duration (years)	0.011	-0.023	0.020
	(0.010)	(0.020)	(0.031)
Institutional quality (WGI)	-0.052*	0.107	-0.113
	(0.027)	(0.140)	(0.150)
Constant	0.879***	1.607	0.218
	(0.322)	(2.270)	(1.034)
Number of observations	74	74	74
Adjusted R^2	0.971	0.941	
Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)			
†Endogenous in DPD estimation			

Table D4: Test statistics *log per capita GDP* (high-income countries)

Test	**Statistic**	**p-value**	**Result**	H_0 **(Null Hypothesis)**
Hausman	$\chi^2(7) = 25.76$	0.006	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 0.00$	1.000	Fail to Reject	RE present
Arellano-Bond AR(1)	$z = 0.57$	0.566	Fail to Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = 0.47$	0.638	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(60) = 73.54$	0.112	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(60) = 16.84$	1.000	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(20) = 1.12$	1.000	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = 0.01$	1.000	Fail to Reject	Exogenous instruments

Appendix D: GDP Regression Results (Continued)

Table D5: Results: *log per capita GDP* (middle-income countries)

	(1) OLS	(2) FE	(3) DPD
Lag(1) log GDP per capita (USD)	0.805***	0.635***	0.824***
	(0.034)	(0.086)	(0.047)
log per capita Internet users†	0.027***	0.028***	0.034***
	(0.005)	(0.010)	(0.009)
log per capita aid (USD)†	-0.002	0.003	-0.003
	(0.003)	(0.012)	(0.009)
Life expectancy at birth†	-0.003***	-0.011	-0.003
	(0.001)	(0.009)	(0.003)
log per capita fixed capital formation (USD)	0.191***	0.323***	0.175***
	(0.030)	(0.063)	(0.043)
Secondary education, duration (years)	0.024***	-0.014	0.024***
	(0.005)	(0.021)	(0.007)
Institutional quality (WGI)	-0.055***	-0.047	-0.055***
	(0.012)	(0.044)	(0.016)
Constant	0.501***	1.791**	0.504**
	(0.127)	(0.749)	(0.219)
Number of observations	392	392	392
Adjusted R^2	0.983	0.940	
Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)			
†Endogenous in DPD estimation			

Table D6: Test statistics *log per capita GDP* (middle-income countries)

Test	Statistic	p-value	Result	H_0 (Null Hypothesis)
Hausman	$\chi^2(7) = 52.59$	0.000	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 17.40$	0.000	Reject	RE present
Arellano-Bond AR(1)	$z = 3.86$	0.000	Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = 0.56$	0.575	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(138) = 152.67$	0.186	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(138) = 72.90$	1.000	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(24) = -1.23$	1.000	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = -3.76$	1.000	Fail to Reject	Exogenous instruments

Appendix D: GDP Regression Results (Continued)

Table D7: Results: *log per capita GDP* (low-income countries)

	(1) OLS	(2) FE	(3) DPD
Lag(1) log GDP per capita (USD)	0.812***	0.747***	0.623***
	(0.047)	(0.109)	(0.091)
log per capita Internet users†	0.026***	0.042**	0.044**
	(0.010)	(0.020)	(0.019)
log per capita aid (USD)†	0.034	-0.026	-0.001
	(0.022)	(0.065)	(0.058)
Life expectancy at birth†	-0.002	-0.010	-0.008
	(0.002)	(0.012)	(0.007)
log per capita fixed capital formation (USD)	0.153***	0.238***	0.256***
	(0.028)	(0.071)	(0.073)
Secondary education, duration (years)	0.016	0.330***	0.062
	(0.018)	(0.085)	(0.059)
Institutional quality (WGI)	-0.094***	0.022	-0.064
	(0.033)	(0.092)	(0.051)
Constant	0.432**	-0.678	1.380**
	(0.201)	(0.873)	(0.699)
Number of observations	168	168	168
Adjusted R^2	0.948	0.884	
Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)			
†Endogenous in DPD estimation			

Table D8: Test statistics *log per capita GDP* (low-income countries)

Test	Statistic	p-value	Result	H_0 (Null Hypothesis)
Hausman	$\chi^2(7) = 38.06$	0.000	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 0.00$	1.000	Fail to Reject	RE present
Arellano-Bond AR(1)	$z = 1.87$	0.061	Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = 2.06$	0.039	Reject	No 2nd order autocorr
Sargan	$\chi^2(82) = 74.29$	0.715	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(82) = 35.39$	1.000	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(14) = 2.94$	0.999	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = 1.72$	0.632	Fail to Reject	Exogenous instruments

Appendix E: Exports Regression Results

Table E1: Results: *log exports per capita* (all countries)

	(1) OLS	(2) FMM	(3) FE	(4) DPD	(5) DPD
Lag(1) log exports per capita	0.957***	0.959***	0.837***	0.929***	0.889***
	(0.011)	(0.010)	(0.048)	(0.027)	(0.053)
log per capita Internet users†	0.009	0.017***	0.020*	0.023**	0.034**
	(0.007)	(0.005)	(0.010)	(0.010)	(0.017)
log per capita aid (USD)†	-0.001	0.002	0.010	-0.012	-0.012
	(0.004)	(0.005)	(0.015)	(0.014)	(0.012)
Life expectancy at birth†	-0.001	-0.002**	0.012	-0.005	-0.000
	(0.001)	(0.001)	(0.008)	(0.004)	(0.004)
log per capita fixed cap (USD)	0.082***	0.076***	0.143***	0.112***	0.103**
	(0.015)	(0.014)	(0.031)	(0.030)	(0.045)
Secondary education (years)	0.014**	0.013**	0.028	0.025**	0.010
	(0.006)	(0.006)	(0.043)	(0.011)	(0.010)
Institutional quality (WGI)	-0.057***	-0.057***	-0.110**	-0.035*	-0.048*
	(0.013)	(0.012)	(0.044)	(0.018)	(0.025)
Time					-0.001
					(0.011)
Income level					-0.065
					(0.058)
Time x Income level‡					0.001
					(0.005)
Constant	-0.088		-0.647	0.208	0.419
	(0.094)		(0.632)	(0.171)	(0.291)
Number of observations	629	629	629	629	629
Adjusted R^2	0.992		0.889		

Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)

†Endogenous in DPD estimation; ‡Interaction term

Appendix E: Exports Regression Results (Continued)

Table E2: Test statistics *log exports per capita* (all countries)

Test	**Statistic**	**p-value**	**Result**	H_0 **(Null Hypothesis)**
Hausman	$\chi^2(7) = 31.43$	0.000	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 2.60$	0.053	Reject	RE present
Arellano-Bond AR(1)	$z = 2.63$	0.008	Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = 0.08$	0.940	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(146) = 163.72$	0.150	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(146) = 110.26$	0.988	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(24) = 20.88$	0.646	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = 1.95$	0.582	Fail to Reject	Exogenous instruments
Note: DPD test statistics for equation (4) in Table E1				

Appendix E: Exports Regression Results (Continued)

Table E3: Results: *log exports per capita* (high-income countries)

	(1) OLS	(2) FE	(3) DPD
Lag(1) log exports per capita (USD)	1.002***	0.646***	1.122***
	(0.045)	(0.185)	(0.269)
log per capita Internet users†	0.026	0.054	0.028
	(0.020)	(0.046)	(0.054)
log per capita aid (USD)†	-0.024*	-0.052	-0.044
	(0.014)	(0.038)	(0.037)
Life expectancy at birth†	-0.005	0.020	-0.013
	(0.004)	(0.029)	(0.033)
log per capita fixed capital formation (USD)	-0.013	0.245*	-0.054
	(0.049)	(0.128)	(0.143)
Secondary education, duration (years)	0.016	-0.003	0.056
	(0.013)	(0.022)	(0.085)
Institutional quality (WGI)	-0.021	-0.093	0.018
	(0.035)	(0.179)	(0.362)
Constant	0.641	0.192	0.283
	(0.482)	(2.473)	(1.802)
Number of observations	72	72	72
Adjusted R^2	0.967	0.860	
Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)			
†Endogenous in DPD estimation			

Table E4: Test statistics *log exports per capita* (high-income countries)

Test	Statistic	p-value	Result	H_0 (Null Hypothesis)
Hausman	$\chi^2(7) = 5.03$	0.657	Fail to Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 2.75$	0.049	Reject	RE present
Arellano-Bond AR(1)	$z = 0.44$	0.662	Fail to Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = -0.27$	0.789	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(60) = 66.21$	0.271	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(60) = 16.70$	1.000	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(20) = -0.19$	1.000	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = -0.05$	1.000	Fail to Reject	Exogenous instruments

Appendix E: Exports Regression Results (Continued)

Table E5: Results: *log exports per capita* (middle-income countries)

	(1) OLS	(2) FE	(3) DPD
Lag(1) log exports per capita (USD)	0.935***	0.809***	0.909***
	(0.014)	(0.058)	(0.034)
log per capita Internet users†	0.006	0.021	0.026**
	(0.010)	(0.014)	(0.012)
log per capita aid (USD)†	-0.001	0.013	0.000
	(0.004)	(0.016)	(0.011)
Life expectancy at birth†	-0.002**	0.010	-0.001
	(0.001)	(0.011)	(0.004)
log per capita fixed capital formation (USD)	0.094***	0.162***	0.093***
	(0.019)	(0.041)	(0.033)
Secondary education, duration (years)	0.023***	0.043	0.026***
	(0.006)	(0.052)	(0.009)
Institutional quality (WGI)	-0.064***	-0.082*	-0.053***
	(0.015)	(0.048)	(0.020)
Constant	-0.009	-0.517	0.123
	(0.123)	(0.855)	(0.226)
Number of observations	389	389	389
Adjusted R^2	0.980	0.916	
Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)			
†Endogenous in DPD estimation			

Table E6: Test statistics *log exports per capita* (middle-income countries)

Test	Statistic	p-value	Result	H_0 (Null Hypothesis)
Hausman	$\chi^2(7) = 18.71$	0.009	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 5.91$	0.008	Reject	RE present
Arellano-Bond AR(1)	$z = 2.67$	0.008	Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = -0.12$	0.901	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(138) = 173.80$	0.021	Reject	Valid overid restrictions
Hansen	$\chi^2(138) = 77.01$	1.000	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(24) = 3.82$	1.000	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = -0.67$	0.964	Fail to Reject	Exogenous instruments

Appendix E: Exports Regression Results (Continued)

Table E7: Results: *log exports per capita* (low-income countries)

	(1) OLS	**(2) FE**	**(3) DPD**
Lag(1) log exports per capita (USD)	0.947***	0.855***	0.846***
	(0.024)	(0.078)	(0.061)
log per capita Internet users†	0.009	0.017	-0.007
	(0.013)	(0.018)	(0.022)
log per capita aid (USD)†	0.049*	0.052	0.069
	(0.026)	(0.068)	(0.058)
Life expectancy at birth†	0.004	0.018	0.015
	(0.003)	(0.015)	(0.024)
log per capita fixed capital formation (USD)	0.080**	0.112**	0.153**
	(0.031)	(0.053)	(0.064)
Secondary education, duration (years)	-0.055*	-0.215**	-0.123
	(0.033)	(0.101)	(0.142)
Institutional quality (WGI)	-0.096**	-0.247**	-0.150*
	(0.045)	(0.114)	(0.081)
Constant	-0.109	0.308	-0.366
	(0.337)	(0.925)	(0.746)
Number of observations	168	168	168
Adjusted R^2	0.964	0.833	
Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$; (heteroskedasticity robust standard errors)			
†Endogenous in DPD estimation			

Table E8: Test statistics *log exports per capita* (low-income countries)

Test	**Statistic**	**p-value**	**Result**	H_0 **(Null Hypothesis)**
Hausman	$\chi^2(7) = 8.70$	0.275	Fail to Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 0.00$	1.000	Fail to Reject	RE present
Arellano-Bond AR(1)	$z = 0.78$	0.437	Fail to Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = 0.66$	0.511	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(82) = 93.73$	0.177	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(82) = 30.57$	1.000	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(14) = -0.71$	1.000	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = -3.03$	1.000	Fail to Reject	Exogenous instruments

Appendix F: Market Cap Regression Results

Table F1: Results: *log market cap per capita* (all countries)

	(1) OLS	**(2) FMM**	**(3) FE**	**(4) DPD**	**(5) DPD**
Lag(1) log mkt cap per capita	0.866***	0.932***	0.453**	0.821***	0.830***
	(0.059)	(0.015)	(0.185)	(0.116)	(0.092)
log per capita Internet users†	0.192***	0.193***	0.251***	0.249***	0.116*
	(0.030)	(0.024)	(0.064)	(0.062)	(0.069)
log per capita aid (USD)†	0.012	0.037***	-0.004	0.077	0.019
	(0.018)	(0.014)	(0.060)	(0.083)	(0.061)
Life expectancy at birth†	-0.006*	-0.010***	-0.003	0.001	0.013
	(0.004)	(0.003)	(0.037)	(0.015)	(0.012)
log per capita fixed cap (USD)	0.036	-0.005	0.702***	0.047	-0.019
	(0.071)	(0.036)	(0.255)	(0.181)	(0.139)
Secondary education (years)	0.034	0.150***	0.101	-0.033	-0.020
	(0.023)	(0.035)	(0.199)	(0.092)	(0.049)
Institutional quality (WGI)	0.008	0.045	0.088	-0.005	0.100
	(0.064)	(0.056)	(0.245)	(0.094)	(0.119)
Time					0.098***
					(0.036)
Income level					0.045
					(0.223)
Time x Income level‡					-0.022
					(0.017)
Constant	1.504***		-0.691	1.629*	0.335
	(0.405)		(3.228)	(0.926)	(1.212)
Number of observations	353	353	353	353	353
Adjusted R^2	0.941		0.776		
Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)					
†Endogenous in DPD estimation; ‡Interaction term					

Appendix F: Market Cap Regression Results (Continued)

Table F2: Test statistics *log market cap per capita* (all countries)

Test	**Statistic**	**p-value**	**Result**	H_0 **(Null Hypothesis)**
Hausman	$\chi^2(7) = 131.69$	0.000	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 1.84$	0.088	Reject	RE present
Arellano-Bond AR(1)	$z = 1.83$	0.067	Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = 1.01$	0.313	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(143) = 133.59$	0.702	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(143) = 74.61$	1.000	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(24) = -1.52$	1.000	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = 1.10$	0.777	Fail to Reject	Exogenous instruments
Note: DPD test statistics for equation (4) in Table F1				

Appendix F: Market Cap Regression Results (Continued)

Table F3: Results: *log market cap per capita* (high-income countries)

	(1) OLS	(2) FE	(3) DPD
Lag(1) log market capitalization per capita (USD)	0.972***	0.649***	0.926***
	(0.097)	(0.154)	(0.213)
log per capita Internet users†	0.244***	0.211**	0.344***
	(0.062)	(0.096)	(0.131)
log per capita aid (USD)†	-0.040	0.122**	0.069
	(0.037)	(0.059)	(0.072)
Life expectancy at birth†	0.015	0.121	-0.124
	(0.022)	(0.115)	(0.160)
log per capita fixed capital formation (USD)	-0.005	0.370**	0.283
	(0.164)	(0.155)	(0.262)
Secondary education, duration (years)	0.046	0.410***	0.036
	(0.066)	(0.056)	(0.149)
Institutional quality (WGI)	-0.121	-0.159	0.329
	(0.128)	(0.636)	(1.052)
Constant	-0.377	-11.589	7.816
	(1.365)	(7.846)	(10.621)
Number of observations	64	64	64
Adjusted R^2	0.940	0.850	
Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$; (heteroskedasticity robust standard errors)			
†Endogenous in DPD estimation			

Table F4: Test statistics *log market cap per capita* (high-income countries)

Test	Statistic	p-value	Result	H_0 (Null Hypothesis)
Hausman	$\chi^2(7) = 61.03$	0.000	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 0.000$	1.000	Fail to Reject	RE present
Arellano-Bond AR(1)	$z = 0.82$	0.411	Fail to Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = 1.05$	0.293	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(56) = 61.31$	0.291	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(56) = 5.65$	1.000	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(37) = 3.73$	1.000	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = -3.32$	1.000	Fail to Reject	Exogenous instruments

Appendix F: Market Cap Regression Results (Continued)

Table F5: Results: *log market cap per capita* (middle-income countries)

	(1) OLS	(2) FE	(3) DPD
Lag(1) log market capitalization per capita (USD)	0.810***	0.379*	0.718***
	(0.081)	(0.210)	(0.178)
log per capita Internet users†	0.257***	0.256***	0.331***
	(0.048)	(0.085)	(0.080)
log per capita aid (USD)†	0.016	-0.077	0.063
	(0.027)	(0.079)	(0.075)
Life expectancy at birth†	-0.011**	-0.037	-0.023
	(0.005)	(0.041)	(0.030)
log per capita fixed capital formation (USD)	-0.007	0.835***	0.094
	(0.071)	(0.305)	(0.298)
Secondary education, duration (years)	0.059**	-0.220	0.021
	(0.026)	(0.203)	(0.070)
Institutional quality (WGI)	0.018	0.037	-0.009
	(0.091)	(0.312)	(0.150)
Constant	2.473***	3.556	3.515**
	(0.858)	(3.478)	(1.775)
Number of observations	241	241	241
Adjusted R^2	0.886	0.768	
Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)			
†Endogenous in DPD estimation			

Table F6: Test statistics *log market cap per capita* (middle-income countries)

Test	Statistic	p-value	Result	H_0 (Null Hypothesis)
Hausman	$\chi^2(7) = 93.31$	0.000	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 1.20$	0.137	Fail to Reject	RE present
Arellano-Bond AR(1)	$z = 1.67$	0.095	Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = 0.62$	0.533	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(131) = 119.64$	0.752	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(131) = 49.28$	1.000	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(24) = 1.50$	1.000	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = 0.52$	0.914	Fail to Reject	Exogenous instruments

Appendix F: Market Cap Regression Results (Continued)

Table F7: Results: *log market cap per capita* (low-income countries)

	(1) OLS	(2) FE	(3) DPD
Lag(1) log market capitalization per capita (USD)	0.987***	0.806***	0.656
	(0.057)	(0.153)	(0.459)
log per capita Internet users†	0.138*	0.264*	0.367
	(0.075)	(0.139)	(0.293)
log per capita aid (USD)†	0.082	-0.337	0.013
	(0.120)	(0.415)	(1.105)
Life expectancy at birth†	-0.038*	-0.029	-0.261
	(0.022)	(0.039)	(0.333)
log per capita fixed capital formation (USD)	-0.053	0.121	0.683
	(0.237)	(0.298)	(1.414)
Secondary education, duration (years)	0.622*		3.229
	(0.323)		(4.670)
Institutional quality (WGI)	0.249	0.002	1.360
	(0.317)	(0.377)	(2.108)
Constant	-0.731	4.229	-4.786
	(1.904)	(3.119)	(16.872)
Number of observations	48	48	48
Adjusted R^2	0.927	0.831	
Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)			
†Endogenous in DPD estimation			

Table F8: Test statistics *log market cap per capita* (low-income countries)

Test	Statistic	p-value	Result	H_0 (Null Hypothesis)
Hausman	$\chi^2(7) = 4.75$	0.576	Fail to Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 0.03$	0.434	Fail to Reject	RE present
Arellano-Bond AR(1)	$z = 0.68$	0.497	Fail to Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = 1.05$	0.295	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(45) = 48.47$	0.335	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(45) = 5.22$	1.000	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(13) = 0.00$	1.000	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = -2.64$	1.000	Fail to Reject	Exogenous instruments

Appendix G: UN HDI Regression Results

Table G1: Results: *hdi* (all countries)

	(1) OLS	**(2) FMM**	**(3) FE**	**(4) DPD**	**(5) DPD**
log Internet users†	0.013***	0.013***	0.004***	0.005***	0.016***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.005)
log Official aid (USD)†	-0.013***	-0.013***	-0.001	-0.049***	-0.015
	(0.002)	(0.002)	(0.001)	(0.009)	(0.010)
log Fixed cap form (USD)	0.081***	0.081***	0.015***	0.062***	0.050***
	(0.003)	(0.003)	(0.002)	(0.006)	(0.008)
log Labor force, total	-0.082***	-0.082***	0.076***	-0.033***	-0.051***
	(0.004)	(0.004)	(0.013)	(0.008)	(0.017)
Institutional quality (WGI)	0.005	0.005	0.009**	0.032**	0.006
	(0.006)	(0.006)	(0.005)	(0.014)	(0.017)
Time					-0.006
					(0.004)
Income level					-0.073**
					(0.030)
Time x Income level‡					0.000
					(0.002)
Constant	0.238***		-0.827***	0.712***	0.651***
	(0.045)		(0.182)	(0.128)	(0.163)
Observations	1,054	1,054	1,054	1,054	1,054
Adjusted R^2	0.744		0.674		

Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)

†Endogenous in DPD estimation; ‡Interaction term

Appendix G: UN HDI Regression Results (Continued)

Table G2: Test statistics *hdi* (all countries)

Test	**Statistic**	**p-value**	**Result**	H_0 **(Null Hypothesis)**
Hausman	$\chi^2(5) = 91.20$	0.000	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 2674$	0.000	Reject	RE present
Arellano-Bond AR(1)	z = -2.13	0.033	Reject	No 1st order autocorr
Arellano-Bond AR(2)	z = -0.11	0.912	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(20) = 94.13$	0.000	Reject	Valid overid restrictions
Hansen	$\chi^2(20) = 34.79$	0.021	Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(2) = 2.53$	0.282	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = 13.14$	0.004	Reject	Exogenous instruments
Note: DPD test statistics for equation (4) in Table G1				

Appendix G: UN HDI Regression Results (Continued)

Table G3: Results: *hdi* (high-income countries)

	(1) OLS	**(2) FE**	**(3) DPD**
log Internet users†	0.012***	0.007***	0.012***
	(0.002)	(0.002)	(0.002)
log Official aid (USD)†	-0.001	-0.002*	0.005
	(0.002)	(0.001)	(0.005)
log Fixed capital formation (USD)	0.010*	0.021***	0.013
	(0.006)	(0.002)	(0.009)
log Labor force, total	-0.017***	0.038	-0.023*
	(0.006)	(0.023)	(0.012)
Institutional quality (WGI)	0.050***	-0.007	0.047***
	(0.005)	(0.005)	(0.016)
Constant	0.714***	-0.193	0.630***
	(0.074)	(0.320)	(0.139)
Observations	125	125	125
Adjusted R^2	0.702	0.826	

Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)

†Endogenous in DPD estimation

Table G4: Test statistics *hdi* (high-income countries)

Test	**Statistic**	**p-value**	**Result**	**H_0 (Null Hypothesis)**
Hausman	$\chi^2(5)$ = -9.33	-	-	RE are consistent
Breusch and Pagan	$\chi^2(1) = 196$	0.000	Reject	RE present
Arellano-Bond AR(1)	$z = 0.77$	0.441	Fail to Reject	No 1st order autocorr
Arellano-Bond AR(2)	z = -1.07	0.286	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(20) = 14.24$	0.818	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(20) = 17.51$	0.620	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(2)$ = -0.66	1.000	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = 0.34$	0.951	Fail to Reject	Exogenous instruments

Appendix G: UN HDI Regression Results (Continued)

Table G5: Results: *hdi* (middle-income countries)

	(1) OLS	**(2) FE**	**(3) DPD**
log Internet users†	0.011***	0.005***	0.006***
	(0.002)	(0.001)	(0.002)
log Official aid (USD)†	-0.015***	0.000	-0.028**
	(0.003)	(0.002)	(0.012)
logFixed capital formation (USD)	0.056***	0.017***	0.036***
	(0.005)	(0.002)	(0.008)
log Labor force, total	-0.055***	0.064***	-0.027***
	(0.006)	(0.015)	(0.008)
Institutional quality (WGI)	0.016**	0.011*	0.010
	(0.006)	(0.006)	(0.016)
Constant	0.466***	-0.676***	0.788***
	(0.064)	(0.223)	(0.158)
Observations	631	631	631
Adjusted R^2	0.470	0.671	

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$; (heteroskedasticity robust standard errors)

†Endogenous in DPD estimation

Table G6: Test statistics *hdi* (middle-income countries)

Test	**Statistic**	**p-value**	**Result**	H_0 **(Null Hypothesis)**
Hausman	$\chi^2(5) = 60.04$	0.000	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 1869$	0.000	Reject	RE present
Arellano-Bond AR(1)	$z = -1.60$	0.111	Fail to Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = -0.30$	0.767	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(20) = 60.30$	0.000	Reject	Valid overid restrictions
Hansen	$\chi^2(20) = 26.07$	0.163	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(2) = 3.35$	0.187	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = 1.48$	0.687	Fail to Reject	Exogenous instruments

Appendix G: UN HDI Regression Results (Continued)

Table G7: Results: *hdi* (low-income countries)

	(1) OLS	(2) FE	(3) DPD
log Internet users†	0.016***	0.000	0.007***
	(0.003)	(0.001)	(0.002)
log Official aid (USD)†	-0.063***	-0.003	-0.036***
	(0.008)	(0.002)	(0.011)
log Fixed capital formation (USD)	0.060***	0.003	0.058***
	(0.007)	(0.003)	(0.015)
log Labor force, total	-0.018**	0.205***	-0.024
	(0.009)	(0.029)	(0.020)
Institutional quality (WGI)	0.009	0.013*	0.008
	(0.013)	(0.008)	(0.021)
Constant	0.628***	-2.660***	0.286
	(0.109)	(0.409)	(0.205)
Observations	298	298	298
Adjusted R^2	0.409	0.698	

Note: *** p<0.01, ** p<0.05, * p<0.1; (heteroskedasticity robust standard errors)

†Endogenous in DPD estimation

Table G8: Test statistics *hdi* (low-income countries)

Test	Statistic	p-value	Result	H_0 (Null Hypothesis)
Hausman	$\chi^2(5) = 80.13$	0.000	Reject	RE are consistent
Breusch and Pagan	$\chi^2(1) = 711$	0.000	Reject	RE present
Arellano-Bond AR(1)	$z = -0.60$	0.547	Fail to Reject	No 1st order autocorr
Arellano-Bond AR(2)	$z = -1.23$	0.218	Fail to Reject	No 2nd order autocorr
Sargan	$\chi^2(20) = 25.44$	0.185	Fail to Reject	Valid overid restrictions
Hansen	$\chi^2(20) = 18.73$	0.540	Fail to Reject	Valid overid restrictions
Diff-in-Hansen (GMM levels)	$\chi^2(2) = 1.58$	0.453	Fail to Reject	Exogenous instruments
Diff-in-Hansen (exog regressors)	$\chi^2(3) = 5.00$	0.171	Fail to Reject	Exogenous instruments