By Eric Shih, Kenneth L. Kraemer, *and* Jason Dedrick

IT DIFFUSION IN DEVELOPING COUNTRIES

Policymakers need to recognize that developing economies have different drivers for IT investment than their wealthier brethren.

There is widespread belief among international agencies and development specialists in the potential value of information technology (IT) to support economic and human development [11, 12]. Some question whether IT alone can have a major impact on the standard of living in developing countries, but most see it offering access to vital information and services such as weather forecasting, commodity prices, health care, and education. However, a significant digital divide exists between richer and poorer countries in the use of IT and the availability of complementary assets such as telecommunications networks and skilled IT professionals. This gap has led to a public debate about what can be done to promote greater IT use so that developing countries can achieve the types of benefits already being enjoyed in the industrialized world.

The problem currently is diagnosed by some as resulting from a lack of affordability of computer hardware, with various low-cost computers such as a $100 laptop being offered as solutions. Others view the problem as part of a broader set of issues that include poverty, lack of infrastructure and inadequate education. To inform these policy discussions, it is important to understand the factors that influence IT use at the country level and whether there are differences in these factors between developed and developing countries. Policy efforts based on incorrect assumptions are likely to have little impact on IT diffusion or economic development.

In order to offer empirically based insights into the drivers of IT use, we analyzed data from 44 countries over a 15-year period and found markedly different results for developing and developed countries. These results have implications for government policymakers and others interested in promoting IT investment for economic development.

Many in the development community believe that IT can serve as a catalyst to help poorer countries accelerate development [11, 12]. As later adopters, they have access to lower cost, easier-to-use technology, and can learn from the experience of developed countries in using IT. However, studies that compare developed and developing countries find that IT investment has a positive and significant relationship with productivity growth at the macroeconomic level in developed countries, but not in developing countries [6].

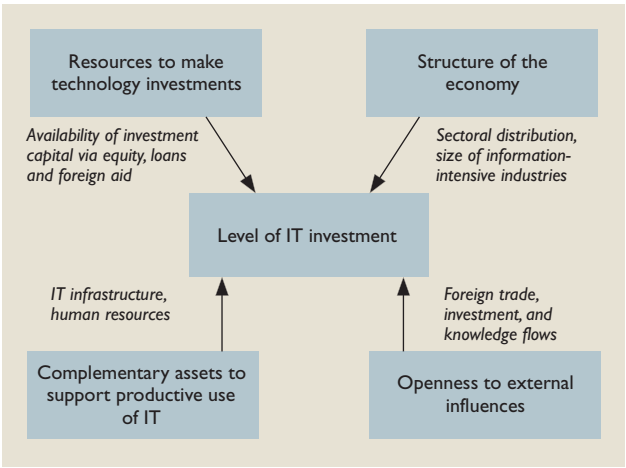

Figure 1. Conceptual framework.

One likely reason is the low level of IT investment in poorer countries. Even in the U.S., the impacts of IT on productivity and growth only became widely recognized by economists in the late 1990s, after decades of cumulative investment [7]. Bell and Pavitt [2] argue that growth in developing countries comes from technological accumulation, which is "... an evolutionary process of continuous innovation and imitation." Given their historically low levels of IT spending, it is likely that most developing countries have not reached a level of accumulated investment needed to achieve measurable productivity gains. Hence the question of what factors influence country-level IT investment is very important, as IT investments over time will influence when countries might achieve significant economic impacts.

Only a few empirical studies have looked at the factors influencing the level of IT investment. One study of 11 Asia-Pacific countries found that IT investment was associated with diffusion of telecommunications infrastructure, education levels, technical skills, and the percent of the economy in services industries [8]. Another study of 89 countries found that computer hardware imports, an indicator of IT investment, were associated with educational attainment, openness to imports and property rights protection [3].

Another study, based on a flexible accelerator investment model, finds differences between developed and developing countries in terms of factors influencing IT investment [10]. Here, we further examine the issue of developed and developing country factors using a seemingly unrelated regression (SUR) model that focuses on factors that can be addressed by policy choices of both governments and international organizations.

Factors Linked to IT Investment

Theoretical and empirical studies have noted that the process of technology diffusion occurs unevenly across national boundaries because of differences in national environments and links to the global economy. Although various studies have shown that IT investment is correlated with the level of national wealth, other factors have been shown to be significant as well: resources for technology investments, structure of the economy, complementary assets, and openness to external influences (see Figure 1).

Resources for technology investments. Investing in new technologies requires the availability of capital, either from external sources such as foreign direct investment and foreign aid or from internal sources such as equity markets and domestic loans and credits. For both developing and developed countries, access to loans and credits is likely to be important. For developed countries, we would expect that access to capital via the equity markets would also be important, as those countries have more well-developed stock markets that reward companies for making productivity-enhancing investments in IT. For most

developing countries, we would not expect equity markets to be mature enough to be a significant source of capital. However, we would expect foreign aid to play a significant role, as it can serve as a substitute for scarce domestic capital and also stimulate private investment.

Structure of the economy. When we look across countries, we find a wide disparity in the extent to which national economies have evolved from agriculture to manufacturing and finally to information-intensive services. Unlike agriculture, manufacturing, or even retail services, which involve production or movement of physical goods, sectors such as financial services primarily involve manipulation and transmission of information. In financial services, the use of IT is much more pervasive, as IT can greatly increase the efficiency and reduce the cost of manipulating and transmitting information. We thus would expect countries with larger financial services sectors to have higher rates of investment in IT. Earlier research has found a significant positive association between the size of a country's services sector and IT investment [3, 8, 9].

Type of variable	Factor	Measure	Definition
Independent variables	Resources to make technology investments	Log (AIDGDP)	Foreign aid as a percent of GDP
		Log (CDTGDP)	Loans and credits made to the private sector as a percent of GDP
		Log (MARGDP)	Total market capitalization as percent of GDP
	Structure of the economy	Log (FIRE)	Finance, insurance and real estate as percent of total country employment
	Complementary assets	Log (TELDEN)	Main phone lines per 100 people
		Log (EDTERP)	Tertiary school enrollment as percent of relevant age group
	Openness to foreign influences	Log (TRDGDP)	Trade as percent of GDP
		Log (FDIGDP)	Inward foreign direct investment as percent of GDP
Control variable	Country wealth	Log (GDP/CAP	GDP per capita
Dependent variable	IT investment (Diffusion)	Log (IT/GDP)	IT spending on hardware as percent of GDP

Figure 2. Measures and definitions for diffusion factors.

We further expect the positive impact of the financial services sector on IT investment to be more pronounced in developed countries than developing countries. For developed countries, there is likely to be some point at which the increasing scale of the finance sector requires accelerating investments in IT to handle the volume and complexity of transactions through increased automation.

Complementary assets. IT use requires the presence of complementary assets such as a telecommunications infrastructure and skilled human resources. The importance of a telecommunications infrastructure is supported by empirical studies showing a positive association between teledensity indicators and IT investment [3, 8, 9].

Also vital is the presence of human resources with appropriate skills and access to sources of information on how to use the technology. Educated workers more readily adjust to the implementation of new technologies and an educated workforce reduces opposition to social changes associated with adoption of new technologies [9]. Also, human resources such as IT professionals, engineers, and management specialists are likely to be especially important, not only for their technical knowledge, but for their access to information through personal networks. Strong empirical support has been found between education levels and IT use at the country level [3, 8, 9].

However, it is possible that the impact of complementary assets is less significant in developed countries, which have widespread diffusion of telecommunications and high education levels. Once the level of complementary assets reaches a certain level, the marginal impact of an additional phone line, or of an extra percentage point in tertiary education, may be diminished. In contrast, we would expect that the impact of complementary assets would be greater in developing countries, which are still in the process of creating adequate levels of such assets [6].

Openness to external influences. Effective use of IT requires a broad range of knowledge, both technical and managerial, much of which can be found beyond the borders of any country. Foreign trade facilitates the diffusion of such knowledge across borders as it "provides channels of communication that stimulate cross-border learning of production methods, product design, organizational methods, and market conditions" [4]. Additionally, foreign direct investment (FDI) has a positive impact on technical progress in the host country [1].

We would expect that greater external openness should lead to more rapid diffusion of technologies into a country. Multinational corporations tend to bring with them business practices that rely more heavily on IT, and thus are more likely to invest in IT themselves and require that their suppliers make similar investments. They also bring knowledge of how to use IT productively. Openness to trade and FDI also may expose a national economy to greater interna-

tional competition, driving IT investment by local firms as a tool for survival. Finally, doing business internationally may force firms to adopt IT in order to meet the requirements of foreign suppliers or customers.

Thus, we would expect countries with higher levels of trade and FDI, relative to GDP, would invest more in IT. We expect that the impacts would be more significant for developing countries, which are likely to be farther behind the global frontier in adopting IT-enabled business practices and thus should benefit more from external sources of knowledge.

Developing Countries		Years	Developing Countries		Years
1	Australia	1985-99	1	Argentina	1991-99
2	Austria	1985-99	2	Brazil	1985-99
3	Belgium	1988-99	3	Bulgaria	1991-99
4	Canada	1985-99	4	Chile	1985-99
5	Denmark	1985-99	5	China	1987-99
6	Finland	1985-99	6	Colombia	1985-99
7	France	1985-94	7	Czech Republic	1993-99
8	Germany	1991-99	8	Egypt	1989-99
9	Ireland	1985-99	9	Greece	1985-99
10	Italy	1985-99	10	Hungary	1992-99
11	Japan	1985-99	11	Indonesia	1985-99
12	Netherlands	1985-99	12	Israel	1985-99
13	New Zealand	1986-99	13	South Korea	1985-99
14	Norway	1985-99	14	Malaysia	1985-99
15	Singapore	1985-99	15	Mexico	1988-99
16	Spain	1985-99	16	Philippines	1985-99
17	Sweden	1985-99	17	Poland	1985-99
18	Switzerland	1991-99	18	Portugal	1985-99
19	United Kingdom	1985-99	19	Romania	1996-99
20	United States	1985-99	20	Russia	1993-99
			21	Slovak Republic	1994-99
			22	Slovenia	1993-99
			23	Turkey	1985-99
			24	Venezuela	1985-99

* In current year US$

Table 1. Data availability by country.

Methods, Data, and Models

We model IT spending against the foregoing factors to identify which are determinants of IT investment in the entire sample of countries. We then divide the sample into developed and developing countries, in order to test the hypothesis that these groups will have different characteristics in terms of IT investment drivers.

We used multiple measures to capture the factors hypothesized to influence the level of investment in IT as shown in Figure 2. And because IT investments are likely to correlate significantly with the wealth or level of economic development in a country, we control for wealth, and measure it in terms of gross domestic product (GDP) per capita.

Data. We use spending on computer hardware as a percent of GDP as a measure of IT investment. International Data Corporation (IDC) provided data on IT investments from 1985 to 1999 for 44 countries. The series captures the value of shipments, which is the revenue paid to vendors for hardware and systems. Countries included in our analysis and their respective beginning and ending year of available data are presented in Table 1. Data on the structure of national economies comes from the International Labour Organization's *2000 Yearbook of Labour Statistics* and World Bank's 2004 *World Development Index.* We standardized monetary findings in current year U.S. dollars.

Model estimation. Our model combined data in a cross-section and over time in one single model. To correct for skewed data, natural log transformation was applied to the variables.[1] The regression estimates are reported in Table 2.

We hypothesized that factors driving IT investments may differ between developed and developing countries for reasons presented in the conceptual framework. We define developed countries as those the World Bank defines as high-income countries (n=20), and developing countries as all others (n=24). The developed countries have an average GDP per capita of $18,945 over the 15 years in our sample, while developing countries averaged $2,749.

We used SUR and estimated two sets of parameters for developed and developing countries.[2] We did this instead of estimating two different equations because we assume that there exists some factor, such as global economic conditions, that impacts both developed and developing countries and is not captured in the model.[3] The SUR model resulted in a higher adjusted R^2 than the initial regression model (0.866) (see Table 3). The SUR results contrast with the initial regression model and provide us with a clearer picture of differences in determinants across the two samples.

Developing Countries Have Different IT Drivers

The results provide empirical support for most of our predictions about the factors shaping IT investments across national economies. The factors explain 80% of the variation in IT investments. These results indicate the usefulness of our conceptual model (see Fig-

[1]For countries that receive no foreign aid, it would have been impossible to take natural log transformations. Therefore, a small constant of 0.0001 was added to level of foreign aid of all countries at all years to avoid censoring.

[2]The fixed effects pooled model is

$$\ln(Y_{i,t}) = \beta_1 \ln(X_{1,i,t}) + \beta_2 \ln(X_{2,i,t}) + \ \ldots\ + \beta_7 \ln(X_{9,i,t}) + \sum_{i=1}^{N} \omega_i \alpha_i + \sum_{t=1}^{T-1} \lambda_t \gamma_t + \varepsilon_{it}$$

[3]As a caution against the possibility of reverse causality, we conducted a Granger causality test where reverse causation is absent when $f(lnx_{i,t} \mid lnx_{i,t-1}, lnX_t, lny_{t-1}) = f(lnx_{i,t} \mid lnx_{i,t-1}, lnX_t)$ where lnX_t is a set of lnx's other than lnx_i. That is, all other independent variables are used as control variables in the test of causation. A simple linear model was used in estimation. Test results indicate that all $F_{(1,538)}$'s 1.198, p>0.10, which suggests that lny_t does not cause lnxt and therefore reverse causation is not an issue.

ure 1). More importantly, the SUR model provides strong empirical support for our hypothesis that the factors shaping investment in developing countries differ from those in developed ones. Here, we discuss our major findings, organized around the four categories in the conceptual framework (see Figure 1).

Resources for technology investments. We tested three different types of financial resources that can be channeled into IT investments and found that for the full sample, the level of foreign aid a country receives (AIDGDP), capitalization of equity markets (MARGDP), and level of credits and loans to the private sector (CDTGDP) all influence IT investments. However, when examining the differences between developed and developing countries, we found differences in the type of resources each utilizes. In the developed countries the only significant variable was market capitalization, while in developing countries both foreign aid and credits and loans to the private sector were significant. This makes sense in that foreign aid can be a significant source of capital for developing countries while developed countries rarely receive such aid. On the other hand, developed countries generally have more well-developed equity markets from which to raise capital for IT investments.

Independent Variables	Coefficient	SE
Log (AIDGDP)	0.035**	0.007
Log (CDTGDP)	0.005**	0.001
Log (MARGDP)	0.021**	0.009
Log (FIRE)	0.124**	0.018
Log (TELDEN)	0.003**	0.001
Log (EDTERP)	-0.013	0.029
Log (TRDGDP)	0.139	0.087
Log (FDIGDP)	0.020**	0.008
Log (GDPCAP)	0.558**	0.087
R^2 = 0.816 Adj. R^2 = 0.792 SE = 0.125 N = 521		
* $p < 0.10$ ** $p < 0.05$		

Table 2. Factors shaping IT investments across all countries.

Independent Variables	Developing Countries		Developing Countries	
	Coefficient	SE	Coefficient	SE
Log (AIDGDP)	-0.009	0.010	0.018*	0.010
Log (CDTGDP)	0.002	0.001	0.004**	0.001
Log (MARGDP)	0.044*	0.025	-0.015	0.009
Log (FIRE)	0.101**	0.023	0.032	0.027
Log (TELDEN)	0.001	0.001	0.007**	0.001
Log (EDTERP)	-0.014	0.013	0.019**	0.004
Log (TRDGDP)	-0.141	0.172	0.632	0.104
Log (FDIGDP)	0.016*	0.009	0.047**	0.012
Log (GDPCAP)	-0.057	0.148	0.934**	0.107
R^2 = 0.866 Adj. R^2 = 0.846 SE = 0.108 N = 521				
* $p < 0.10$ ** $p < 0.05$				

Table 3. Factors shaping IT investments in developing and developed countries.

Structure of the economy. For the full set of countries, IT investment is positively and significantly related to the share of the economy in information-intensive industries (FIRE). The split analysis of developed and developing countries revealed, however, that the effect is significant only in the developed countries. This finding seems reasonable given developing countries generally have a much smaller share of the economy in information-intensive sectors, so that the size of these sectors has not reached critical mass as significant drivers of IT investment. On the other hand, developed countries have likely surpassed that threshold.

Complementary assets. We did not find an effect for education (EDTERP) or density of telephone lines (TELDEN) to significantly impact IT investments for the full sample. However, the SUR model revealed that a significant effect does exist for developing countries but not developed countries. This supports our hypothesis that telecommunications infrastructure has reached a point of saturation in developed countries and therefore has an insignificant marginal impact on IT investment. On the other hand, most developing countries lag behind in telecommunication infrastructure; thus increases in teledensity can still foster additional investment in computers. Similar arguments can be made for human resources. Developed countries already have the necessary human capital in place while developing countries are building their human capital; therefore, we only observe an effect of human capital in developing countries.

Openness to external influences. There was no effect for level of international trade (TRDGDP) on IT investment either overall or for the split country analyses. Based on this result, we would conclude that trade in itself does not create competitive pressure or carry with it IT-enabled business practices sufficient to have an impact on IT investment.

However, level of foreign investment (FDIGDP) was significantly related to IT investments as hypothesized. Although positive and significant for both groups, the effect of foreign investment was stronger in developing countries. This is consistent with the argument that developing countries have more to gain from inflows of knowledge associated with foreign investment.

Conclusion

The analysis leads to two general conclusions that have important practical implications. First, our study shows that wealth is the single most important factor influencing IT investment but that other factors are significant as well. This raises the question of how important GDP per capita is relative to other

factors for developing countries, given that relative wealth is difficult to directly influence through policy changes, at least in the short run. To estimate relative effects, we look at the standardized betas in the model and find the highest standardized beta goes to GDPCAP (0.879), followed by FDIGDP (0.559), and EDTERP (0.236). This suggests that the next two factors, which are both directly addressable by policy choices, have roughly as much influence as national wealth on IT investment.

Second, the factors driving diffusion are different for developing economies than for developed ones. The availability of investment resources (loans and foreign aid), the level of complementary assets, and openness to foreign investment all play a role in driving IT investment in developing countries. Again, these factors can be influenced by national development policies as well as by financial aid from international development agencies.

Policy Implications

For developing countries to realize the potential benefits of IT, policymakers should look for ways to promote IT investment as well as developing investment resources, complementary assets, and openness to external influences. The empirical findings suggest several policy recommendations.

- *Resources for technology investments.* The analysis suggests that availability of loans and credit is crucial for developing countries, which means that the maturity and dynamics of the financial system is a key variable for those countries. Case studies have shown that banks in some developing countries perceive IT investment as risky, and they can be hesitant to extend credit for such investments. In such cases, government policy could increase the availability of credit through the banking system by providing loan guarantees or other incentives. The connection between foreign aid and IT investment suggests a role for developed country governments and international organizations such as the World Bank in providing capital to developing countries specifically for IT investments.
- *Complementary assets.* Increasing investment in telecommunications infrastructure, which is usually best accomplished by policies that introduce competition into that sector, will promote IT diffusion. Over the longer term, increasing tertiary education levels will also be beneficial in developing skills needed for IT use. While our data only measured the impact of tertiary education in general, there is evidence from country case studies that focused efforts to train people in IT skills is important as well.
- *Openness to external influences.* Encouraging foreign investment by removing restrictions and improving the environment for foreign capital is likely to have a major impact. In cases such as Mexico and Brazil, economic liberalization that led to investment by foreign multinationals stimulated IT use. These multinationals required suppliers to adopt IT, and created competitive pressure for domestic firms to invest in IT [5]. Although the benefits of FDI may be greater for firms engaged in the global economy, there may be spillovers for purely local firms through local competition and knowledge transfer. C

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This research has been supported by grants from the U.S. National Science Foundation and the IBM Corporation. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors only.

Eric Shih (e_shih@yahoo.com) is an associate professor of marketing at the Graduate School of Business, Sungkyunkwan University, Korea.

Kenneth L. Kraemer (kkraemer@uci.edu) is a research professor in the Paul Merage School of Business and Co-Director of the Personal Computing Industry Center (PCIC) at the University of California, Irvine.

Jason Dedrick (jdedrick@uci.edu) is Senior Fellow and Co-Director of the Personal Computing Industry Center (PCIC) at the University of California, Irvine.

DOI: 10.1145/1314215.1314223