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Determinants of ICT Expenditure Using Logit Transformation for Proportion Data Analysis

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Abstract

Observations of the recent developments in hardware, software, and the Internet reinforce the importance and role of Information and Communication Technology (ICT). This paper utilizes logit transformation for proportion data analysis to empirically investigate determinants of ICT expenditure. A fixed-effects panel data model was used to examine the factors influencing expenditure on ICT. Two regressions were estimated for a sub-sample of 11 Asia-Pacific countries and 22 OECD countries.

Keywords: ICT Expenditure, OECD, Asia- Pacific.

Introduction

Technology simplifies human work and changes our life style creating a new civilization. The world today is facing a new revolution commonly denoted as the Information and Communication Technology Revolution (Gordon, 2000).[1] As the earlier industrial revolution created machines to replace manual work, the Information and Communication Technology (ICT) revolution are spurring technological inventions in the design, production, and distribution of goods and services (Cohen, Delong & Zysman, 2000).

It is appropriate to begin this paper by examining the need to study the ICT revolution and to determine the reasons for importance given in research to ICT. ICT has seldom been the target of careful and comprehensive development planning.[2] Lately, economists have realized that ICT has begun to play a crucial role in economic growth and development (Ahmad, Schreyer & Wolfl, 2004). For both developed and developing countries, issues in ICT, Internet, and mobile phone technological development require serious consideration, given the market trends (ITU,

[1] Gordon described the ICT Revolution as the 'New Economy' (the Internet and the associated technical change in computers and telecommunications) to be equal, or even more important, than the Second Industrial Revolution of 1860-1900.

[2] Sichel (1997) pointed out that in the 1970s and 1980s, ICT expenditure was too small as a percentage of investment or total GDP to have an impact on the economy.

2002). Today, economists realize that ICT and Internet-related issues are significant components of economic activity.

In recent years, many studies found in the literature have concentrated on the impact of ICT on productivity or output growth either in micro- or macro-level analyses. Studies that focused on the determinants of ICT expenditure are very limited. This paper contributes to the literature on the subject in three respects. First, this paper is the first of its kind to use ICT expenditure as a percentage of GDP. Second, this study uses logit transformation of fixed-effects proportion data analysis to empirically investigate ICT expenditure and Internet usage. Third, the empirical analysis compares two sub-samples, 22 OECD and 11 Asia-Pacific countries.

The rest of the paper is structured as follows. Section two summarizes the literature on the subject. In section three, the theoretical background, data, and regression analysis are presented. The empirical methodology is presented in section four. Section five discusses the empirical results, and section six provides policy implications and a conclusion.

Literature Review

The literature on ICT can be categorized into three types. First, there are studies that concentrate on the impact of computers on productivity and economic growth. Second, there are studies of the impact of IT (which includes computers) on firms, sectors, or cross-country. Third, there are broader studies of computers, software, and telecommunication technologies.

The significant impact of ICT can be seen in the large number of articles written by many authors over the past decade.[3] Some of these authors include Oliner and Sichel (2000), Brynjolfsson and Yang (1996), Jorgenson and Stiroh (1995), Sichel (1997,1999), Kraemer and Dedrick (1994, 2001), and Motohashi (1997) who have all examined the remarkable impact of ICT. Most of these studies are reviewed in various papers edited by Pohjola (2001). However, most of these studies using time series macro data, cross-section, or firm-level micro data investigated the impact of ICT, IT, or computers on productivity or output growth. None of the studies in the literature studied the determinants of ICT expenditure.

Two relevant papers that relate to the ICT expenditure determinants of this study are Caselli and Coleman (2001) and Kraemer and Dedrick (1994). However, Caselli and Coleman used computer equipment imports, a proxy for computer equipment investment, as the dependent variable. They found that computer adoption is linked with high levels of human capital, manufacturing trade openness, high rates of investment per worker, and a smaller share of agriculture in GDP.

Kraemer and Dedrick (1994) using data for 12 Asia-Pacific countries for the period of 1984-1990 found that GDP per capita, education levels, share of employment in the service sector, and number of telephone lines per 100 people correlated with IT investment. However, IT

[3] I have also included some studies in a broader ICT category that use computers or IT data only.

expenditure before and after 1990 was significantly different in terms of components, primarily because of the development of software and the Internet.

Theory, Data and Regression Analysis

Theory

Theoretically, the Diffusion of Innovations Theory provides a base for ICT research. The theory is used as a foundation for many technical ICT research projects. Roger's (1962) Diffusion of Innovations Theory (DOI*)* illustrates the model of adoption, describes the means of diffusion, and predicts the success of a new invention. The study of diffusion of the innovation process can be done at a micro level using individuals and/or firms, or at the macro level when taking into consideration economic development or technological advances. The diffusion of innovation process consists of four major elements: the innovation process itself, marketing process through a number of channels, long run S-curved learning impact, and the human interaction and acceptance/rejection.

Gomulka (1971) suggests that theoretically, diffusion of innovation depends on

- The degree of openness and receptiveness within a country, which is influenced by the transportation sector, the communication sector, and the educational levels of the population.
- The growth rates of exports.

Baskerville and Pries-Heje (2003) relate the DOI model to the IT application. Using three DOI models, the interactive model, the linked-chain model and the emergent model, the authors linked the theory with IT diffusion. However, these models are beyond the focus of this study.

Data

This study uses data from International Telecommunication Union (ITU) and World Development Indicators 2003. The dependent variable is ICT expenditure as a percentage of GDP. The data for ICT expenditure as a percentage of GDP is available annually for a period of nine years from 1992 to 2000. A logit model with panel data was used so that the empirical analysis would not be undermined by the small sample size. For comparison purposes, the data were split into two samples with the first one for 22 OECD countries and the second for 11 Asia Pacific countries. Independent regressions were estimated for the two samples.

ICT Expenditure Regression

Because ICT research is primarily related to innovation or technology diffusion, the choice of variables was broadly based on the DOI theory. See Table 1 for acronym, descriptions, expected signs, and justifications for using the variable in the ICT expenditure regression.

AGGDP and INDGDP reflect the state of the economy. Initially, services as a share of GDP was also included in the analysis, but the three variables are highly correlated. Therefore, the services as a share of GDP was dropped to control for the correlation effect. The correlation between AGGDP and INDGDP is not worrisome. Caselli and Coleman (2001) found that an economy that concentrates on agriculture is likely to invest less in computer investment or broadly ICT related expenditure. In contrast, if the level of industrialization is high, generally there is a higher tendency to spend more on ICT related services. The level of investment in a country, using gross capital formation (INV), is expected to boost the demand for ICT and related services, thus increasing ICT expenditure.

One of the important determinants that attract foreign direct investment (FDI) is the availability of productive physical infrastructure in the host country (partly communication, telecommunication, and related services), given that it positively affects productive efficiency (Lall et al., 2002). Conversely, expertise and technological transfer through foreign direct investment per capita (FDIPER) definitely enhances usage and expenditure of ICT in the host country.

The concentration of an economy in the production of high-technology exports (HITEX), such as aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery, is an important factor triggering ICT investment. Similarly, high import volumes of communication related equipment, computers, and related products (ICTIMP) suggest that the country encourages technology transfer and availability of sophisticated information technology and thus ICT usage.

Lately, many governments are committed to improving physical telecommunication, communications facilities, and other ICT infrastructure. Governments also allocate funds to increase access to telecommunication, enhance and upgrade communication services, and facilitate and strengthen IT related services. However, Ghali (1998) argues that theoretically larger government consumption (GFCE), a proxy for government size, could also undermine private sector involvement in the economy. Therefore, government consumption could have either a positive or negative impact on ICT expenditure.

The degree of employment in industry (EMPIND) and employment in services (EMPSER) are likely to contribute to higher ICT expenditure. Higher employment in industries, especially capital-intensive industry, complement usage of ICT. Likewise, higher employment in the service industry encourages ICT expenditure, especially in wholesale and retail trade, restaurants and hotels, transportation, storage, and communications. Also finance, insurance, real estate, and business services are likely to be increasingly dependent on ICT devices. Higher demand for ICT-related services encourages development of human resources in ICT and other skill areas that are crucial to the information economy.

GDP growth (GDPGR) signals development of the country, which in turn supports higher investment in numerous sectors of the economy. Higher GDPGR indicates potential future market growth. Further, market growth indirectly stimulates the activities of various sectors of the economy, which in turn enhances mobilization of financial resources and other technological resources to aid in developing and exploiting the opportunities of the information economy. When various sectors of the economy prosper, demand for ICT-related services increases.

R&D expenditure (R&D) is spending on applied research and advancement work leading to new devices, products, or processes to increase the stock of knowledge. Higher R&D expenditure indicates policies that promote technology enhancement and increased technical sophistication in the economy, which in turn promotes ICT usage. The GDP deflator (INFLA) is used to measure the inflation rate in the country. Lower inflation means lower hardware and software prices, cheaper ICT costs; hence stimulation of ICT investment.

Empirical Methodology

Turning to the empirical methodology, the logit model that is widely used in applied econometric applications was employed. In many technology diffusion models, economists generally use the logit model. The reduced form of a logit model is

$$P[Y_{it} = 1] = \frac{e^{\beta' X_{it}}}{1 + e^{\beta' X_{it}}} \quad (1)$$

where, Y is the dependent variable.
X are the independent variables.
i = 1,……….N indexes group.
t = 1,……….T(i) indexes period.
X = k x n matrix, β = 1 x k matrix, and Y = 1 x n matrix.

Data are available for ICT expenditure in terms of percentage of GDP and for the number of Internet users as a percentage of population. Thus, the proportion data analysis of a logit model seemed appropriate. According to Greene (2002), a common solution to this sort of data is to do a logit transformation as shown below. The transformation produces a linear regression that makes the estimation simple, compared to a nonlinear logit model.

The observed dependent variable $P(Y_{it})$ is approximation of the population quantity, $\pi_{it} = F(\beta' X_{it})$. Thus

$$P(Y_{it}) = F(\beta' X_{it}) + \varepsilon_{it} = \pi_{it} + \varepsilon_{it} \quad (2)$$

where $E[\varepsilon_{it} / X_{i1} \ldots X_{iT(i)}] = 0$,

$$\text{var}[\varepsilon_{it} / X_{i1} \ldots X_{iT(i)}] = \frac{\pi_{it}(1-\pi_{it})}{n_{it}}$$

Regression (2) above can be estimated using nonlinear weighted least squares to account for heteroscedasticity. However, strict monotonicity of $F(\beta' X_{it})$ provides an inverse. By employing a Taylor Series approximation to equation (2) around point $\varepsilon_{it} = 0$, it follows that

$$F^{-1}(P(Y_{it})) = F^{-1}(\pi_{it} + \varepsilon_{it}) \approx F^{-1}(\pi_{it}) + \left[\frac{dF^{-1}(\pi_{it})}{d\pi_{it}}\right]\varepsilon_{it}$$

$$F^{-1}(P(Y_{it})) = \beta' X_{it} \text{ and } \frac{dF^{-1}(\pi_{it})}{d\pi_{it}} = \frac{1}{dF(\pi_{it})/d\pi_{it}} = \frac{1}{f(\pi_{it})} \quad (3)$$

Equation (3) can be rewritten as

$$F^{-1}(P(Y_{it})) \approx \beta' X_{it} + \frac{\varepsilon_{it}}{f(\pi_{it})} \quad (4)$$

The approximation gives:

$$F^{-1}(P(Y_{it})) = z_{it} = \beta' X_{it} + \mu_{it} \quad (5)$$

where

$$E[\mu_{it}] = 0 \text{ and } \quad \text{var}[\mu_{it}] = \frac{F(\pi_{it})[1 - F(\pi_{it})]}{n_{it}(f(\pi_{it}))^2}$$

Notice that equation (5) is a heteroscedastic linear regression.

The following transformation was done. Using the logit model in (1) and rewriting it gives:

$$1 - \pi_{it} = 1 - \frac{e^{\beta' X_{it}}}{1 + e^{\beta' X_{it}}} = \frac{1 + e^{\beta' X_{it}} - e^{\beta' X_{it}}}{1 + e^{\beta' X_{it}}} = \frac{1}{1 + e^{\beta' X_{it}}}$$

$$\frac{\pi_{it}}{1 - \pi_{it}} = \frac{e^{\beta' X_{it}}}{1 + e^{\beta' X_{it}}} \frac{1 + e^{\beta' X_{it}}}{1} = e^{\beta' X_{it}} \quad (6)$$

Taking logarithms on both sides of equation (5) produces

$$\ln\left(\frac{\pi_{it}}{1 - \pi_{it}}\right) = \ln\left(e^{\beta' X_{it}}\right) = \beta' X_{it} \quad (7)$$

The transformation produces a linear regression of the form

$$Y_{it} = \beta' X_{it} + \varepsilon_{it} \quad (8)$$

Based on Greene (2003), for the group data case or proportion data, when one performs the transformation, the weighted least squares with dependent variable[4]

$$\text{logit}\ (P(Y_{it})) = \ln\left[\frac{\pi_{it}}{1-\pi_{it}}\right] = \beta' X_{it} \qquad (9)$$

Since ordinary least squares (OLS) generate consistent but inefficient estimates, then the weight would be $w_{it} = [n_{it}\lambda_{it}\ (1-\lambda_{it})\ ]^{0.5}$. Using this transformation, one can estimate Ordinary Least Squares accounted for heteroscedasticity.[5] This gives minimum chi-square estimates of β.

In the econometrics literature, cross-sectional time-series models are called panel data. In this study, time-series of the observations are at individual rather than aggregate level. In a pooled observation situation, estimating the OLS would yield a biased estimate. When the number of individuals is small, a dummy could be fit for each individual, called the fixed effects (FE) model, because the regression line is increased or decreased by a fixed amount for each individual. Since the time series in our case is only available for a few years in the panel, the FE model was estimated. The FE model is a common choice among macroeconomists when the data is a macro panel. With the country specific constant, it is possible to obtain unobservable country specific heterogeneity. According to Hsiao (2003), in an FE model, regressors may be correlated with the individual effects, while the error term μ_{it} is uncorrelated across country (i) and year (t).

In summary, FE logit transformation of proportion data model was estimated in the form of:

$$\text{logit}(P(Y_{it})) = \ln\left[\frac{\pi_{it}}{1-\pi_{it}}\right] = \eta_1\delta_{1it} + \eta_2\,\delta_{2it} + \dots\dots\dots + \beta' X_{it} + \mu_{it} \qquad (10)$$

where π_{it} is the dependent variable in country i =1,……, N, year t = 1,….,T(i).
X_{it} is the vector of independent variables.
δ_{jit} is the group specific year dummy variables.
η_i is the individual specific constant or the country effect.
μ_{it} is a classical disturbance with $E[\mu_{it}] = 0$, $\text{var}[\mu_{it}] = \sigma^2_{\mu}$.
White's robust, heteroscedasticity corrected covariance matrix was used.

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[4] Two limitations apply: First, the transformation is not possible when the dependent variable is zero or one. In this case, the result will be a missing value. The second limitation is that when the fraction is from large population; the variance will be low, leading to low standard error and high t-ratios in the minimum chi-square regression.

[5] See Greene (2003) for a detailed discussion. The transformation produces a heteroscedastic linear regression. Alternatively one can use the logistic likelihood to estimate the proportions data:

$$\ln L = \sum_{i=1}^{n} n_i [P_i \ln F(\beta' X_i) + (1-P_i)\ln(1-F(\beta' X_i))].$$

Amemiya (1985) pp. 275-280 has shown that the transformation above yields the same properties as a maximum likelihood estimator.

Empirical Results

The primary objective of this study was to find the determinants of ICT expenditure. The means and standard deviation of the variables used in this study are given in Tables 2. The results of FE logit transformation of ICT expenditure for 22 OECD countries and 11 Asia-Pacific countries are shown in Table 3. In this regression, using panel data, ICT expenditure as a percentage of GDP was regressed on various independent variables. For the OECD, eight of the 12 variables were statistically significant at the 10% level or better. On the other hand, nine of the 12 variables were significant in Asia-Pacific at 10% level or better.

Agriculture share of GDP (AGGDP) is significantly negatively related to ICT in both OECD and Asia-Pacific at 1% and 5% levels, respectively. The negative sign on the parameter estimate of (AGGDP) agrees with the results of Caselli and Coleman (2001). The estimates imply that higher ICT expenditure is associated with a smaller share of agriculture in GDP. Similarly, for the industrial share of GDP (INDGDP), a statistically significant positive relationship was found in both OECD and Asia-Pacific. This indicates that industrial growth encourages ICT expenditure.

For the gross capital formation (INV) variable in the OECD, the result implies that investment has a positive impact on ICT expenditure. However, INV is not a statistically significant determinant of ICT expenditure in the Asia-Pacific regression. The results also indicated that FDIPER is statistically significant at the 1% level in Asia-Pacific. This suggests that the positive impact on ICT expenditure is larger as FDI flow increases. FDI is not statistically significant in the OECD, which implies that ICT expenditure is not dependent on foreign investment.

The high-technology export (HITEX) variable is positively related to ICT at the 5% level in the OECD regression but not significant for the Asia-Pacific region. This result suggests high-technology related export production is not a positive influence on ICT in the Asia-Pacific sample. The parameter estimates for ICTIMP, proxy for openness in the ICT sector, show a relatively strong and significantly positive effect on ICT expenditure in Asia-Pacific compared to OECD. This is in line with our expectation that the Asia-Pacific region encourages technology transfer and availability of sophisticated IT.

However, the proxy for government size (GFCE) differs considerably in the estimates in Asia-Pacific and OECD. In the Asia-Pacific sample, government consumption expenditure is highly positively significant at the 1% level. Governments in most Asian countries make a concerted effort to utilize ICT as a critical component of an increasingly technology-dependent economy. GFCE is not significant in the OECD sample. Perhaps this is not surprising in developed OECD countries since the private sector's role is more dominant.

The empirical findings of the two employment variables, EMPIND and EMPSER, were statistically significant and positive in the OECD as well as in the Asia-Pacific sample. Comparatively, employment in services has more impact on ICT in Asia-Pacific than OECD. The opposite results prevail for EMPIND; the coefficient of Asia-Pacific is relatively very small. However, the statistical significance is greater for both variables in the OECD.

The results also revealed that GDP growth is statistically significant at the 1% level in Asia Pacific, but not significant in OECD. Asian Development Outlook (2004) reported that the economic growth rate in developing Asia was 6.3% in 2003 and an average growth rate of 8-10% in the 1990s. This suggests that the region is the most dynamic growth area in the world. In both samples, R&D expenditure was not a statistically significant determinant of ICT expenditure. GDP deflator (INFLA) was inversely correlated and statistically significant at the 1% and 5% levels respectively, in OECD and Asia-Pacific. The magnitude of the inflation coefficient in Asia-Pacific is larger than OECD, which suggests that price variation is larger in the former.

Implications and Future Policy Issues

This paper contributes to the literature of Economics of Information and Communication Technology. Using the existing data for the 1992-2000 period for ICT expenditure, fixed-effects panel data analysis of logit transformation was used to empirically estimate the regression. The regression estimates indicate that ICT expenditure is associated with a smaller share of agriculture in GDP, a larger share of industry in GDP, higher employment in industry and services, higher ICT imports, and lower inflation in both the OECD and Asia-Pacific samples. FDI and government size were positively linked with ICT expenditure in Asia-Pacific but not in the OECD sample. On the other hand, gross capital formation is positively related to ICT in the OECD but not in Asia-Pacific.

Though this study did not provide comprehensive conclusive results, it still provides some insights into certain policy issues. First, ICT import as a proxy for trade openness in the sector was positively related to ICT expenditure. This implies that open international market access in the ICT sector is crucial for the development of ICT in a country. Second, government consumption expenditure, a proxy for government size, was highly significant in the case of the Asia-Pacific. Perhaps governments in Asia should reduce their involvement after having provided well-developed infrastructure and let the private sector participate more in the ICT sector. The transition to the private sector would increase competition and efficiency. Third, the empirical results also showed that FDI is crucial for ICT development in the Asia-Pacific. Policies need to be implemented to encourage more FDI in the region.

In conclusion, the development of ICT will continue, becoming more sophisticated because ICT diffusion plays an important role in human life. The fast-changing ICT trends have become particularly pertinent to consumers, firms, and governments that face new challenges and pressures at a global level. Instead of looking at the impact of ICT on productivity or economic growth, broader studies should include positive and negative externalities of ICT, which would be more useful in understanding ICT diffusion.

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Appendix

Table 1. Variables, Descriptions and Their Relationships with ICT Expenditure

	Description	**Expected sign**	**Rationale**
AGGDP	Agriculture (% of GDP)	–	Agriculture-based economy is likely to spend less on ICT expenditure.
INDGDP	Industry (% of GDP)	+	Higher tendency to spend on ICT if industrialization is prominent.
INV	Gross Capital formation (constant 1995 US $)	+	Higher investment means higher potential for ICT expenditure.
FDIPER	Foreign Direct Investment per capita	+	Higher FDI means higher technology transfer, enhancing ICT investment.
HITEX	High Technology Exports (current US$)	+	Likely to use ICT more.
ICTIMP	Communications, computer, etc. (% of service imports).	+	Higher import of ICT related goods or raw materials means the country supports trade openness in the sector.
GFCE	General Government Final consumption expenditure (Constant 1995 US$)	Ambiguous	To capture the role of government spending on ICT expenditure.
EMPIND	Employment in industry (% of active population).	+	Higher employment in industry complements capital-intensive (ICT) expenditure.
EMPSER	Employment in services (% of economically active population).	+	Service industries use more ICT devices, thus encouraging ICT expenditure.
GDPGR	GDP growth (annual %)	+	Higher GDP growth stimulates ICT expenditure.
R&D	R & D expenditure as a percentage of GNI	+	Higher R&D expenditure indicates technology sophistication, thus promoting ICT expenditure.
INFLA	GDP deflator	–	Lower inflation means lower hardware and software prices, cheaper ICT expenditure, higher ICT investment.

Table 2. Descriptive Statistics of ICT Expenditure

Variables	**Units**	**OECD**		**ASIA-PACIFIC**	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
ICT	% of GDP	-2.709	0.332	-3.061	0.598
AGGDP	% of GDP	1.421	0.703	2.129	0.774
INDGDP	% of GDP	3.509	0.172	3.560	0.217
INV	constant 1995 US $	3.127	0.240	3.280	0.264
FDIPER	constant 1995 US $	22.263	2.647	21.245	3.970
HITEX	current US$	22.818	1.743	20.617	1.858
ICTIMP	% of service imports	3.601	0.293	3.605	0.242
GFCE	constant 1995 US$	2.798	0.356	2.588	0.331
EMPIND	% of active population	3.293	0.236	3.217	0.286
EMPSER	% of active population	4.078	0.298	3.793	0.488
GDPGR	annual %	2.876	3.036	5.032	4.403
R&D	% of GNI	0.534	0.434	0.013	1.119
INFLA	%	0.976	1.133	1.956	1.309

Table 3. Regression Estimates of ICT Expenditure

Variables	**OECD**		**ASIA-PACIFIC**	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
AGGDP	-.6180	-4.599***	-0.466	-2.376**
INDGDP	0.652	1.690*	0.692	2.068**
INV	0.145	1.403*	0.091	0.613
FDIPER	0.029	0.901	0.359	4.412***
HITEX	0.722	1.845**	0.238	0.548
ICTIMP	0.256	1.795*	1.168	2.606**
GFCE	-0.124	-0.665	0.617	3.352***
EMPIND	0.638	2.541**	0.031	1.812*
EMPSER	0.250	2.825***	0.333	1.542*
GDPGR	0.008	1.024	0.132	2.853***
R&D	0.127	0.860	0.058	0.291
INFLA	-0.055	-2.682***	-0.393	-2.540**
R^2	0.702		0.789	
Adjusted R^2	0.670		0.779	
F-Value	27.90***		100.31***	
No. of obs.	198		99	

Note: *** , ** , and * denotes significance at the 1%, 5%, and 10% respectively.