Is Solow's Paradox Absent in World Leading Capital Markets? Econometric Evidence

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Information technology has transformed the traditional economy into digital economy during this century. Yet there has been debate of Solow's Paradox in theoretical and empirical literature. Considering its importance, this research examines its impact on Capital Market Activity by using 47 countries of world's leading capital markets. Market capitalization of listed companies (% of GDP) and Stock traded turnover ratio (%) have been considered as proxies for capital market activity while Information and Communication Technology expenditure is used as development indicators for ICT. Recently development Pooled Mean Group (PMG) approach to cointegration is employed on data of 47 countries capital markets for time span 1990-2012. PMG being a heterogeneous panel estimation technique allows the slope and short run parameters to vary across the countries. Results show the presence of long run relationship between ICT development and capital market activity. Recommendations are made on the basis of empirical findings.

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1. Introduction

This era is of 21st century and the most important invention of this era is ICT development. ICT include internet, personal computers, database management, telephone and cellular communication etc. The world is swiftly becoming an information society with the development of ICT in all aspects of human life. It is an essential infrastructure and a tool of productivity without which our economy cannot function. The use of the resources of information in all the present human societies have resulted in growth and the different societies and fields have used the benefits of ICT with the attention of the established infrastructure. Stock markets are dominant to modern capitalist economies. It signals the economic health of the financial and capital markets. The use of ICT in the stock markets have resulted in its efficiency and reduction in the cost of providing liquidity. It has solved the problems of human errors by replacing the manual market by the ICT based capital market.

The transactions which took hours and days to be completed are now being which took days to be completed are now accomplished in just minutes and seconds. The largest stock exchange in the world is New York stock exchange by both market capitalization and trade value. After 1995, with the greater investment in ICT department, capital markets also showed acceleration and chances of failures reduced. Information asymmetry was also decreased due to public accessibility towards capital markets through active emergence of ICT. ICT plays an important role for making people's investment save in capital markets. Brokerage industry now use their online website for trading and as a result turnover of capital markets increased.

Well known Solow's paradox keeps the for policy makers about the usefulness of ICT, when it comes to investing in ICT. This study attempts to explore the possible absence of Solow's paradox in an ICT intensive environment, i.e. capital markets. This study is an effort to determine the relationship of capital market growth and ICT. The direction of causality of these variables is also determined in this research.

2. Literature Review

Information and Communication Technology plays an important role towards the success and core development of capital markets. The available literature examined suggests that automation of stock exchanges reduce the Cost and inefficiencies associated with share trading, increase trading activity and liquidity. Also adoption of ICT speeds up operations and activities of the exchange and reduces costs associated with manual systems. ICT enables the exchanges extend trading days and hours as cumbersome processes are eliminated. It also eliminates the need for intermediation (stockbrokers) as investors can monitor markets and trade online. The Central Securities Clearing System (CSCS) enables shares to exist in electronic form and thus helps eliminate risks of loss, mutilation and theft of certificates as well as reduce errors and delays. Finally, the adoption of ICT would help in the integration of African Stock Exchanges.

For instance, Clemons and Weber (1990) examined the 1986 big bang reforms of the London Stock Exchange and argued that the adoption of ICT and exchange's new screen based market were a strategic necessity. Brynjolfsson and Yang (1996) using ordinary least square technique with cobb Douglas function in their research, observe that Over the last ten years, there are many firm-level studies examining the relationship between IT investment and firm performance. They found an interesting trend in the results of these studies; the use of larger and more recent datasets tends to generate evidence of its

positive effect on firm performance. In addition, research results in manufacturing often shows stronger effects than studies of services, probably because of better measurement.

Singh, Singh and Weisse (2000) carried out a research on information technology, venture capital and the stock market. They took the sample of 63 developed and developing countries from 1990 to 1995. They investigated the relationship between IT and capital markets. The central analytical and policy question addressed in this paper is what kind of financial system or capital market arrangements are most conducive to fostering information technology and its use in economy. They used variables like GDP, market capitalization, value traded, inverse of turnover ratio, number of listed companies, mobile phone, personal computer, internet host and composite index of ICT development and usage. The results revealed us that for some of the dependent variables, the stock market variables are indeed statistically significant but often have wrong sign or changing values in alternative specification of the equation. This shows that this study does not suggest a robust relationship between stock market development and ICT development and usage.

Lucas, Hobijn and Jovanovic (2001) argue that a major technological innovation causes the stock market to be undervalued until the claims to future dividends enter the stock market via initial public offerings. By using vintage capital model, they found that major technological changes like IT revolution destroys the old firms and disturbs the stock market performance. Weber and Simon (2002) studied the information technology and the New York stock exchange's strategic resources and apply an extended version of the resource-based view (RBV) of competitive strategy to an 18-year history of investments in information technology by the New York Stock Exchange. The extended RBV predicts that firms will use information technology to enhance their existing resources and to create a system of resources for competitive advantage. Variables used in this paper are: listed

firms, market capacity, market quality, trading infrastructure and technological innovation. The data strongly suggest that the NYSE has achieved higher capacity, reduced cycle times, higher quality and greater efficiency from its investment in IT. Technological innovation also seems to have contributed to protecting market share.

Ngassam and Gani (2002) used stock market capitalizations, number of listed companies as dependent variables while telephone, Internet, mobile and television sets as independent variables and data source for these variables is World Bank's world developmental indicators. Different estimation procedures like least square dummy variable regression, OLS and panel corrected standard errors were used on data. 41 countries of low income economies and high income economies were considered and results tell us that digital communication networks are likely to have favorable impact on the economic and financial markets of many nations. The creation of new opportunities for individuals to improve participation in share markets, expands knowledge, speed business transactions and enhances the development of financial sector.

Fling (2005) studied Chinese stock exchange for online securities trading in China. They found that the advantage offered by this technology cannot be fully harvest without fundamental structures and proper corporate governance mechanism in place. IT plays a crucial role in market operations but a successful market infrastructure is a key resource. This study covers the data of 73 securities brokerage firms over the period of 1992 to 2003 from Shanghai stock exchange and Shenzhen stock exchange. Variables examined under this research are market capitalization, stock turnover, total number of investors, total number of shares issued, online trading volume, online trading accounts, internet, telephone, SMS and WAP. Current development level of Chinese securities market is substantially behind than developed markets. It is found that there are non-technological factors that need to be further developed and considered in tandem with

technology application in order to achieve market efficiency and stability.

Hovav and D'Arcy (2005) examine whether the market penalizes firms that produce substandard IT products during 1988-2002. The results show that the market reacts negatively to the production of flawed Information Technology in approximately 50% of the cases. However, this negative market reaction is not statistically significant over extended periods and is limited to announcements involving certain types of defects (i.e., IT products that contain computer viruses). Event study methodology, commonly employed in the accounting and finance literature (e.g., Brown and Warner, 1985; Pruitt and Peterson, 1986; Etebari et al., 1987 and MacKinlay, 1997) is used in this paper. The study concludes that under these present conditions, IT vendors have little economic incentives to invest in defect-free computing.

Bahrami (2008) considered the Iran to see the impact of information and communication technology development on stock market expansion. Her findings suggest that all indicators of ICT development had significant effect on securities exchange development indexes. Bahardawaj et al. (2009) found that IT failures abound but little is known about the financial impact that these failures have on a firm's market value. Using the resource-based view of the firm and event study methodology, this study analyzes how firms are penalized by the market when they experience unforeseen operating or implementation-related IT failures. Their sample consisted of 213 newspaper reports of IT failures by publicly traded firms, which occurred during a 10-year period. The findings show that IT failures result in a 2% average increasing abnormal drop in stock prices over a 2-day event window. The results reveal that market responds more negatively to enactment failures affecting new systems than to operating failures involving current systems. Further, more severe IT failures result in a greater decline in firm value and that firms with a history of IT failures suffer a greater negative impact.

Ezirim, Elike and Muoghalu (2009) used market capitalization, listed securities, value traded, volume traded, turnover, private debt, public bond as dependent variables and number of stockbroker with functional websites, total number of mobile and telephone mainline users and total number of internet users as independent variables. They used the Gompertz technology diffusion model for their research. Results reveal that growth in market capitalization is affected by the level of collaboration between stockbrokers and investors brought about by ICT in the form of internet access, telephone (mainlines and mobile) as well as access to the websites of stockbrokers. Growth in the total volume and value of shares traded is considerably affected by communication technology (telephones). The number of securities listed on the stock markets as well as the growth in federal and state government bonds does not appear to have any significant relationship with the adoption of ICT. Private debt stock appears to have been significantly affected by information and communications technology especially in respect of increase in the number of stockbrokers and access to ICT. Generally, ICT has contributed to growth of the Nigerian capital market, with the effect mostly seen in the availability of information to investors and the improvements in the trading patterns of the Nigeria Stock Exchange.

Bhunia (2011) used modified version of Gompertz technology diffusion model to examine the effect of ICT on the growth of Indian stock exchange. They assessed the data of 2001 to 2011 of market capitalization, stock market volume traded, turnover, number of securities listed, public sector bond, private sector debt and ICT variables as independent variables like total number of internet users, total number of mobile and telephone mainline users and number of stock brokers with functional websites. Capital markets have become exceptionally volatile since the adoption of computer assisted trading approaches as the following increase short-term price volatility and risk. The empirical results disclose that growth in market capitalization

is influenced by internet access, telephone, mobile and access to the website of stockbroker. Growth in total value of shares traded, Private debt stock and turnover in the market are significantly affected by ICT. While the number of securities listed on the stock exchange and public bonds do not get affected by ICT.
Review of literature shows lack of rigorous quantitative analysis of the relationship, we focus on World leading capital markets to quantify the long run relationship between information and communication technology and capital market activity.

3. Objective

This paper analyzes the impact of information and communication technology on world's leading capital markets. Precisely speaking, we investigate the causal long run relationship between information and communication technology (ICT) and capital market growth (CMG).
H_A: There a causal long run relationship between ICT and CMG in World's Leading Capital Markets?
The superjacent can be empirically tested for the set of countries that have substantial data available for the two variables time dimension. To test the cogency of this hypothesis, following data and methodology are employed:

4. Data and Methodology

The data has been collected for a time span of 23 years (1990-2012) of world leading capital market in 47 countries. Selection of these world leading capital markets is on the basis of Financial Development Report 2014 of World Bank. These include the markets of Colombia, Czech Republic, Denmark, Egypt Arab Rep, Finland, France, Germany, Hong Kong, SAR China, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Korea Rep, Kuwait, Malaysia, Mexico, Morocco, Netherlands, Nigeria, Norway, Pakistan, Panama, Peru, Philippines, Poland, Romania, Russian Federation, Saudi Arabia,

Singapore, Slovak Republic, South Africa, Spain, Sweden, Switzerland, Thailand, Tunisia, Turkey, Ukraine, United Arab Emirates, United Kingdom, United States, Venezuela RB and Vietnam. Information and communication technology expenditure is used as independent proxy variable for ICT while Market capitalization of listed companies (% of GDP) and Stocks traded, turnover ratio (%) are used as dependent proxy variables for capital market activity. Although capital market is a much broader term and includes the stock market and the bond market. The chosen variables reflect more of the stock market activity rather than the capital market activity. But here, we shall use these variables as a proxy for the capital market growth indicators because the stock market is a more technology intensive segment of the capital market and its data is also properly maintained and regularly updated.
Model to be estimated is as follows:

$$\boldsymbol{ln}(\mathbf{MCLC_{i,t}}) = \boldsymbol{\alpha_i} + \boldsymbol{\beta_i} \,.\, \boldsymbol{ln}(\mathbf{ICTE_{i,t}}) + \boldsymbol{\varepsilon_{i,t}}$$

and

$$\boldsymbol{ln}(\mathbf{STR_{i,t}}) = \boldsymbol{\alpha_i} + \boldsymbol{\beta_i} \,.\, \boldsymbol{ln}(\mathbf{ICTE_{i,t}}) + \boldsymbol{\varepsilon_{i,t}}$$

$ICTE_{i,t}$ = Information and communication technology expenditure (% of GDP)
$MCLC_{i,t}$ = Market capitalization of listed companies (% of GDP)
$STR_{i,t}$ = Stocks traded, turnover ratio (%)

$$\boldsymbol{\varepsilon_{i,t} = \rho_i\, \varepsilon_{i,t-1} + \omega_{it}}$$

$\varepsilon_{i,t}$ is the disturbance from the panel regression and ϱ_i shows the autoregressive vector of residuals in the i^{th} cross countries. The model parameter α_i allows for the possibility of the country specific fixed-effects and the coefficient of β_i allows for the variation across individual countries.

5. Empirical Analysis

5.1 Panel Unit Root Tests

Panel dataset has time dimension of 23 years which composes a substantial length of time series and therefore, existence of unit roots

in variables cannot be ruled out. Moreover, Eberhardt (2011) supports the use of macro panel estimation techniques if time dimension is greater than 20. To confirm the presence of time series variables contain unit root, we employ three different yet popular tests: Levin et al. (2002) (LLC), Im et al. (2003) (IPS) and Maddala and Wu (1999) (MW) tests. The LL tests are based on homogeneity of the autoregressive parameter, while the IPS tests are based on heterogeneity of autoregressive parameters. Thus, no pooling regressions are associated with IPS tests. MW tests, on the other hand, are based on Fisher type unit root tests that are not restricted to the sample sizes for different samples (Maddala and Wu, 1999).

We use three different tests to confirm our results. Maddala and Wu (1999) argue that "other conservative tests (applicable in the case of correlated tests) based on Bonferroni bounds have also been found to be inferior to the Fisher test." Results from all these tests are given in table 1. The selection of the appropriate lag length was made using the Schwarz Bayesian Information Criterion. Results from all unit root tests suggest that ICTE and MCLC are stationary at 1st difference while STR is stationary at level.

Table 1: Unit Root Tests

Test		ICTE	ΔICTE	MCLC	ΔMCLC	STR
LLC		3.981	-13.755***	7.623	4.016	-2.276**
IPS		9.582	-13.293***	10.188	-5.250***	-5.270***
MW	ADF	85.194	483.309***	97.950	374.756***	152.666***
	PP	88.345	722.931***	263.484	807.502***	182.924***
Remarks		I(1)		I(1)		I(0)

Source: Authors' estimates

Δ denotes first difference. Both variables are taken in natural logarithms. All tests take non-stationarity as null. Note: Table shows the individual statistics and p-values with the lag length selection of one. Intercept is included in all terms with or without first differences. Probabilities of fisher type test are using asymptotic χ^2 distributions while other type of tests assumes asymptotic normality.

5.2 Cointegration Analysis

After investigating stationarity of ICTE, MCLC and STR, we employ cointegration to find the long run relationship among them.

5.3 Panel ARDL Cointegration Approach

Panel ARDL approach to cointegration allows to find cointegration despite different order of integration. In this paper, two of variables are I(1) while one is I(0). Moreover, panel ARDL allows to quantify the long run slope coefficients as well. Such technique devised by Pesaran and Smith (1997) named as pooled mean group (PMG) estimator. It is a suitable for dynamic panels for large number of time observations and large number of groups. PMG estimator allows variation in the intercepts, short-run dynamics and error variances across the groups, but it does not allow long-run dynamics to differ across the groups. PMG estimable model has an adjustment coefficient φ_i that is known as the error-correction term. In fact this error-correction term φ_i tells about how much adjustment occur in each period.

In addition to PMG, two contemporary techniques are also employed, namely; Mean group and Dynamic fixed effects approaches.

5.4 Mean Group (MG)

In Mean group (MG) estimation it becomes possible to estimate regression equations separately for each cross-sectional unit and to compute the mean of the parameters across those units. MG estimation permits not only intercept to vary across individuals but also slope coefficients and error variances to differ as well. MG does not allow for long run homogeneity. For large T and N, MG estimation is consistent, but for small T and N, it is not expected to be efficient.

5.5 Dynamic Fixed Effects (DFE)

Dynamic Fixed Effects (DFE) is old-fashioned pooled estimation which is generated by fixed effects and random effects models. It permits the intercepts to differ across individuals while all other parameters and error variances are restraint to be the same. They are dependent on the assumption that the slope coefficients and error variances are alike. Pooled dynamic effects has a weakness that it leads to inconsistent results even in enormous samples (Pesaran and Smith, 1995). This is because large time span may lead to non-stationarity in the data set.

Table 2: Cointegration Results

	Model – I			Model – II		
	MCLC = f(ICTE)			STR = f(ICTE)		
	MG	DFE	PMG	MG	DFE	PMG
	Long Run Parameters					
ICTE	0.575 (0.071)	0.687 (0.000)	0.202 (0.000)	0.575 (0.071)	0.687 (0.000)	0.202 (0.000)
	Average Convergence Parameter					
φ_i	-0.166 (0.000)	-0.055 (0.000)	-0.061 (0.000)	-0.085 (0.000)	-0.017 (0.018)	-0.022 (0.001)
	Short Run Parameters					
ΔICTE	0.113 (0.000)	0.015 (0.078)	0.136 (0.000)	0.113 (0.000)	0.015 (0.078)	0.136 (0.000)
C	-0.227 (0.654)	-0.398 (0.000)	0.192 (0.000)	0.543 (0.000)	0.115 (0.026)	0.121 (0.000)
Note: In parenthesis, p-values of parameters are given.						
Source: Authors' estimates						

Results in the table 2 are segmented into two models using three techniques of panel cointegration namely; Mean Group (MG), Dynamic Fixed Effects (DFE) and Pooled Mean Group (PMG). In both of the models, PMG is found to be the most suitable technique

by using Hausman test. Therefore, we focus on the results of PMG, in lieu of MG and DFE. These models are explained as follows:
Model – I: reveals the contribution of ICT expenditure (ICTE) in market capitalization of listed companies (MCLC). The relationship is positive and statistically significant as shown by long run parameter. The error correction term (φ_i = - 0.061) is negative and less than 1 in absolute sense. φ_i is statistically significant at 1%. Hence cointegration is demonstrated between ICTE and MCLC.
Model – II: depicts the contribution of ICT expenditure (ICTE) in stocks traded, turnover ratio (%) (STR). The relationship is positive and statistically significant as revealed by long run parameter. The error correction term (φ_i = - 0.022) is negative and less than 1 in absolute sense. φ_i is statistically significant for 1%. It shows presence of cointegration between ICTE and STR.
The two models show that ICT expenditure has a positive and long run statistically significant relationship with the two proxies of capital market i.e. MCLC and STR. Logically, we are directed to investigate the causality between the variables that have shown cointegration. Table 3 depicts the results of panel Granger causality.

5.6 Panel Granger Causality Test

Mehmood & Siddiqui (2013) did similar attempt to find the causality between ICT variables and macroeconomic variables. Here, Table 3 sheds light on the causality between capital market activity and ICT expenditure. A bi-causal relationship is revealed between ICTE and MCLC. It is evident since with the increase in ICT, market value of a stock exchange increase due to facilitation that ICT brings. On the other hand, the growth in the market capitalization in turn increases the demand of the ICT as capital markets around the world are becoming diversified. This has spurred the activities and operations to be carried out via ICT. Moreover, if there is uninterrupted and rapid availability of the internet, the operations and the trading of securities

can be carried out smoothly and real-time. This can further enhance the size of capital market

Table 3: Panel Granger Causality Test.

Causation	F-statistic	p-value	Remarks
Market capitalization of listed companies → Information and communication technology expenditure	74.3208	0.000	Bi-causality
Information and communication technology expenditure → Market capitalization of listed companies	285.342	0.000	
Turnover Ratio of Stocks traded → Information and communication technology expenditure	21.3876	0.000	Bi-causality
Information and communication technology expenditure → Turnover Ratio of Stocks traded	111.063	0.000	
Source: Authors' Estimations			

A bi-causal relationship is also found between ICTE and STR. The advent of online trading has made trading more efficient. As through internet, investors enter into contracts with the brokers to buy or sell securities on behalf of them. This increase in value of stock traded results in the growth of stock market activity. It not only increases the value of trading but also complements the market capitalization by showing if the market size is in lines with trading. Increase in the value of stock traded means more frequent trading which in turn boosts up the turnover ratio of the market. Increase in turnover means growth in the market size and hence growth in the overall economy. When there is growth in the value of stock traded and hence the market size, the stock market activities become tougher and there is a need to constantly update the records of the securities traded and their worth. To make trading easily accessible to the public and to frequently update the records, the stock market requires more use of ICT, which results in increase in the demand of internet facility.

6. Discussion

In this paper, we tried the probe the existence of Solow's paradox in an information intensive sector. It is done by examining the causal long run relationship between ICT and capital market growth comprising of the data of 47 leading capital market from 1990 to 2012 using PMG estimation. The results are in line with theory and previous literature as well. There have been various researches in the past in order to identify the role and impact of ICT in the stock markets and financial institutions for different countries and time period. Singh, Singh and Weisse (2000) found the relationship between the similar variables and found that there was no instant relationship between them. Hovav and D'Arcy (2005) and Bahardawaj (2009) suggested that market reacts negatively to flawed information technology in almost 50% cases. However, our results conform to that of Ngassam and Gani (2003), Bahrami at el. (2003), Ezirim, Elike and Muoghalu (2009). Bhunia (2011) carried out a research for the similar variables, using Gompertz technology diffusion model and revealed that stock markets have become excessively volatile by the adoption of computer assisted trading methods. The use of statistically rigorous methodology can be one of the reasons that this paper is able to affirm the existence of positive relationship between ICT and capital market growth.

Our findings have refuted the Solow's Paradox which can be attributed to information intensive nature of capital markets. Stock markets are thus positively affected by the use of advanced technology and communication means. However, sometimes can by negatively affected depending on factors such as high operating and infrastructure costs, lack of skilled staff to handle to the latest technology, operating failures and defected IT products containing computer viruses. These failures should be cause of concern for policy makers in order to avoid the infamous Solow's Paradox. In a nutshell,

ICT has brought a mention worthy productivity gain in the capital markets. Future research should be focused on the mechanism through with ICT mitigates the information asymmetry in capital markets. Research on less information intensive sectors shall also be worthwhile to question the absence of Solow's Paradox.

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