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The Impact of ICT Penetration on Interest Rates: Panel Analysis

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Abstract

The influences of information and communication technologies (ICT) on interest rates by using four distinct ICT indicators and two different interest rates are investigated. We use an unbalanced data set ranging from 1990 to 2013 for various sample sizes with the largest one containing 799 observations of 86 countries. After controlling for other macroeconomic determinants peculiar to interest rate and taking into account heteroskedasticity and autocorrelation problems in the model, the estimation results disclose an adverse association between information and communication technologies and interest rate. This finding is strong and statistically significant and also does not alter across four different ICT proxies and two distinct interest rates. Therefore we might assert that countries experiencing higher ICT penetration rates face with lower interest rates. This provides policymakers, especially monetary policy authorities, with some useful policy implications.

Keywords: ICT, Interest rate, Panel data, Autocorrelation, Heteroskedasticity.

Bilgi İletişim Teknolojileri (ICT) Yayılımının Faiz Oranlarına Etkisi: Panel Analiz

Öz

Çalışmada bilgi iletişim teknolojilerinin (ICT) faiz oranlarına etkisi dört ICT göstergesi ve iki faiz oranı değişkeni kullanılarak araştırılmıştır. Panel analizde kullanılan dengesiz veri seti 1990-2013 dönemini kapsayan farklı örneklem büyüklüklerinden oluşmakta olup; en büyüğü 799 gözlem ve 86 ülkeyi içermektedir. Faiz oranları ile ilişkili diğer makroekonomik değişkenler kontrol edilip, otokorelasyon ve değişken varyans durumları dikkate alınarak kullanılan modelin uygulama sonuçları ICT ve faiz oranı arasında güçlü ve istatistiksel olarak anlamlı negatif bir ilişkinin varlığına işaret etmektedir. Söz konusu bulgular dört ICT ve iki faiz oranı temsili değişkenleri için geçerliliğini korumaktadır. Dolayısıyla, ICT yayılımı yüksek olan ülkelerde daha düşük faiz oranları görüleceği sonucuna ulaşılmaktadır. Bu bulgu politika yapıcılara, özellikle de para politikası otoritelerine faydalı politika çıkarımları sunmaktadır.

Anahtar Kelimeler: ICT, Faiz oranı, Panel veri, Otokorelasyon, Değişken varyans.

Introduction

The world economies, especially the developed ones, are still under the pressure of the last crisis. Problems in economic growth currently dominate the agenda in most countries. This started a new argument whether this is a new era that economies continue to experience lower growth rates and should get used to it. Or, alternatively, what is next to create increase in productivity hence to reach higher growth rates as its pace back in the pre-crisis

period? Should we foresee a breakthrough change in today's economic outlook? If so, what might be the next channel in this prospect? Nevertheless, assuming that advances in ICT will continue to play a main role in foreseeable future, its effects on different aspects of the economy are worth to investigate.

The basic motivation behind the study is to examine how the ICT affects interest rates. After the work by Yi and Choi (2005) analyzing the effect of the internet on inflation, the literature seems to ignore similar effects of ICT on other macroeconomic or financial variables, particularly on interest rates. Therefore the hypothesis that ICT penetration reduces interest rate is examined using unbalanced panel data. To our knowledge, there is no study in the literature analyzing the association between ICT and interest rates. After controlling for other macroeconomic determinants peculiar to interest rate and taking into account heteroskedasticity and autocorrelation problems in the model, we found a reverse relation between ICT and interest rate and this finding is strong and statistically significant. Meantime this result keeps its validity across four distinct ICT proxies and two different interest rates. Our findings are expected to provide implications especially for policymakers in setting and conducting monetary policies.

The remaining parts of the article proceed as: the next part briefly reviews the literature; data and methodology is explained in the third part; the fourth section provides and evaluates estimation findings; and the last section completes the paper with concluding remarks.

Literature Review

Studies related with ICT and its effects on different aspects of economic variables are recently attracting researchers. A growing body of related literature is about ICT's impacts on economic growth through productivity increase channel. In these studies, the focus generally derives from two main streams. In one of the two, they analyze the relationship between a certain component of ICT, such as the Internet or mobile phones, and a specific country's macroeconomic growth. In the other, studies examine the relationship between ICT and productivity and economic growth measures by using a panel data set of certain country group. Until recently, the related literature has mostly focused on developed economies. As pointed out by Meng and Li (2002), this is primarily due to the fact that developing economies are short of capital investment and knowledge know-how. The study of Chinn and Fairlie (2010) provides the empirical evidence for this argument. Their results indicate that technology penetration in low rates in developing economies stem from disparities in income, telephone density, legal quality, and human capital.

In studies mainly focusing on developed economies such as the US, European countries and Japan, contribution of ICT to economic growth has been the subject of researches since the mid of the 1990s. Studies by Oliner and Sichel (1994, 2000) and Jorgenson and Stiroh (1995, 1999) are regarded as the pioneering ones. Following them, Oliner and Sichel (2003), Jorgenson (2001) and Martinez, Rodriguez and Torres (2010) examine ICT's effect on economic growth in the US while Jorgenson and Motohashi (2005) investigate the same subject on Japan. In addition, there are similar studies conducted on European economies such as Colecchia and Schreyer (2001), Jalava and Pohjola (2002), Jorgenson (2003), Timmer, Ypma and Ark (2003) and Antonopoulos and Sakellaris (2009). In another paper analyzing Finland, Jalava and Pohjola (2008) compare the electricity's and ICT's relative contribution to economic growth. They report that contribution of electricity to growth is smaller yet contribution of ICT to growth is larger in Finland comparing to the US. Bakhshi and Larsen (2005) show that ICT-based technological progress explains about 20% to 30% long-term productivity growth of labor in the UK. They discuss that a permanent rise in the technological progress's growth rate in ICT-specific sector is expected to augment the share of investment spending in GDP but reduce the total rate of depreciation, whereas a surge in the gain of ICT investment is expected to boost both the share of investment expenditure in GDP and the total rate of depreciation.

Schreyer's (2000) view states that ICT's contribution to productivity growth arises from three channels. First, total factor productivity (TFP) of ICT-producing industries is boosted by technological improvements in these industries. Next, falling costs of ICT capital relative to other capital types, especially the labor capital, encourage firms to substitute ICT capital for the other hence result in an increase in labor productivity (LP). Lastly, ICT is capable of producing external economies through improvements in commercial transaction in business world via the Internet. This might hold true especially for financial services industry based on the fact that, thanks to its nature, it is the most and probably the best technology-adapting industry. The evidence for the issue of externalities is also provided by Lopez-Pueyo, Barcenilla-Visus and Sanau (2008). They argue that trade relations act as a channel in transmitting technological externalities.

In an interesting study, Oulton (2012) argues that a two-sector rather than a one-sector growth model is required because of the highly rapid rate at which the prices of ICT products have declined in the past and are expected to decline in the future. In his argument, the two-sector model shows that the principal force behind the growth is not the production of ICT, but the use of ICT. He justifies this thesis by an empirical analysis on 15 European

and 4 non-European economies. Depending on the results, he declares that even an economy with zero ICT production can create advantage via improving terms of trade.

Besides the US, Japan and European economies, the related literature on the rest of the economies have only been recently attracted researchers. In one of these, Engelbrecht and Xayavong (2006) analyze the link between intensity of ICT and growth of labor productivity in 29 industries in New Zealand. Classifying the industries as more and less ICT-intensive, they provide comparisons between the two industry groups' LP growth. Their results indicate that LP growth in more ICT-intensive industries has shown improvements over time comparing to other industry groups. The case of ICT-driven TFP growth case is also analyzed by Antonopoulos and Sakellaris (2009) for Greece. They conclude that, despite being lower relative to the US, the contribution of investments in ICT to economic growth reflects an increase in Greece over the period of 1988-2003. The researchers also report that the most benefited-industries from ICT investments are insurance, finance, real estate and business services industries, and wholesale and retail trade industries.

Investigating the ICT's contribution to economic growth in Singapore over the years of 1990-2008, Vu (2013) finds a same direction strong relationship between the ICT use intensity and value-added and LP growth at industry-level. Vu also shows that ICT investment has contributed to growth rate of GDP 1% on average over the sample period in Singapore. Moreover, the study underlines the result that contribution of ICT manufacturing industry to rate of economic growth reflects a decline and faces a serious restructuring problem. The restructuring problem has also become the subject in Grüner's (2009) study. He investigates the reasons behind the LP growth difference between the US and Europe. The study remarks that for an achievement where even a marginal improvement in ICT may produce significant LP increase, the organization is ought to be restructured.

Seo, Lee and Oh (2009) investigate the dynamic interdependent association between ICT investment and rate of economic growth by using a sample of 29 countries for the period of 1990s. One of their conclusions states that there is no a strong interdependent relationship between economic growth and ICT investment; however, non-ICT investment has a cumulative causal impact on economic growth and a pivotal role in the widening of growth gap. The related literature has recently started to capture the different aspects of ICT. For example, Addison and Heshmati (2003) investigate the determinants of FDI flows from ICT and democratization perspectives while Yartey (2008) examines the interactions between ICT and financial development. Besides Ionescu's (2013) work on the effect of ICT on corruption, Mathur and Ambani (2005), Thadaboina (2009), Malsha, Jayasinghe and Wijeratne (2011) and Ogutu, Okello and Otieno (2014) study the relationship between ICT and agricultural economy.

In another study, Yi and Choi (2005) investigate the Internet's effect on inflation over a panel data set by employing pooled OLS and random effect model. They report that a 1% increase in the ratio of the Internet users to total population leads a 0.04264% drop in the inflation. Since their work; however, we could not detect any similar studies regarding the relationship between ICT (or its components) and macroeconomic (or financial) variables. Based on Yi and Choi's (2005) findings, one can expect that ICT should create a downward pressure on interest rates. The rationale behind this argument stems from two points. First, a drop in the inflation, as proved by Yi and Choi (2005), should result in falling nominal interest rates as well. Second, productivity enhancements created by ICT are expected to cut back interest rates through cost saving side of ICT. Therefore, this is the initial inspiring point that motivated us in conducting this study to examine the association between ICT and interest rates.

Materials and Methods

This study explores the ICT penetration's influence on interest rate by utilizing four ICT proxies and two different interest rates. The dataset used in the panel analyses is unbalanced data and consisting of 24 years between 1990 and 2013 for various sample sizes with the largest one containing 799 observations of 86 countries.

After controlling for other macroeconomic determinants peculiar to interest rate, the following multivariate fixed effect model (FEM) is estimated;

$$INTRATE_{it} = \beta_1 + \beta_2 ICT_{it} + \beta_3 INFLATION_{it} + \beta_4 MONEY_{it} + \beta_5 CREDIT_{it} + \beta_6 ECONGLOB_{it} + \beta_7 FDI_{it} + \beta_8 POP_{it} + u_{it} \quad (1)$$

and the following multivariate random effect model (REM) is estimated;

$$INTRATE_{it} = \beta_1 + \beta_2 ICT_{it} + \beta_3 INFLATION_{it} + \beta_4 MONEY_{it} + \beta_5 CREDIT_{it} + \beta_6 ECONGLOB_{it} + \beta_7 FDI_{it} + \beta_8 POP_{it} + \eta_i + u_{it} \quad (2)$$

where β_{1i} stands for country specific factors is a non-stochastic term; η_i is a stochastic term characterizing the country specific factors; u_{it} is the error term of the model and independently and identically distributed among countries and years.

In the analyses, four different ICT indicators and two distinct interest rates are employed in order to find out how sensitive and robust is the estimation results. The results may be sensitive to which ICT proxy or interest rate is employed in the model. If the result keeps its validity for all ICT and interest rate indicators, then we may claim that our finding is robust with respect to different ICT and interest rate indicators. Table 1 displays variable names, their definitions and sources.

Table 1
List of Dependent and Independent Variables

Variables	Definition	Source
DEPINRATE	Deposit interest rate (%)	WDI
LENDINRATE	Lending interest rate (%)	WDI
INTERNET	Percentage of individuals using the Internet	World Telecommunication/ICT Indicators Database of UN Database http://data.un.org/Data.aspx?d=ITU&f=ind1Code%3a199H#ITU
CELLPHONE	Mobile-cellular telephone subscriptions per 100 inhabitants.	http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx
COMPUTER	Personal computers per 100 inhabitants.	http://www.nakono.com/tekcarta/databank/full/27/
FXBROADBAND	Fixed broadband subscriptions (per 100 people)	International Telecommunication Union, World Telecommunication/ICT Development Report and database.
INFLATION	Inflation, GDP deflator (annual %)	WDI
MONEY	Broad money growth (annual %)	WDI
CREDIT	Domestic credit provided by financial sector (% of GDP)	WDI
ECONGLOB	Economic globalization index	2015 KOF Index of Globalization
FDI	Foreign direct investment, net inflows (% of GDP)	WDI
POP	Population density (people per sq. km of land area)	WDI

Our dependent variable is interest rate. Deposit interest rate (DEPINRATE) and lending interest rate (LENDINRATE) are two proxies for interest rate. Four indicators of ICT penetration are percentage of individuals using the internet (INTERNET), mobile-cellular telephone subscriptions per 100 inhabitants (CELLPHONE), personal computers per 100 people (COMPUTER), and fixed broadband subscriptions per 100 people (FXBROADBAND). Other control variables included in the models are GDP deflator (INFLATION), broad money growth (MONEY), domestic credit provided by financial sector (CREDIT), economic globalization index (ECONGLOB), foreign direct investment (FDI), and population density (POP).

ICT indicators may help to reduce interest rates through two channels. Firstly, as stated by Yi and Choi (2005), ICT indicators improve productivity and thus lower inflation and finally interest rate. Second channel is the cost saving side of ICT. As it is first presumed by Sutherland (1996) and later empirically proved by Claessens, Glaessner and Klingebiel (2001) and Ko (2008), ICT may help reducing operating costs of banking sector and thus making banks to be able to charge lower interest rate. Therefore, our prior expectation for the coefficient of ICT indicators is negative.

In monetary economics, the Fisher Effect summarizes the relationship between inflation and interest rates. Inflation indirectly gives information on uncertainty and economic and politic instability in an economy. Higher inflation rate reflects higher degree of uncertainty and instability, thus the main cause of higher interest rate. Therefore, it is quite possible to expect a positive relation between inflation (INFLATION) and interest rates.

MONEY variable represents money supply in the model. In today's modern monetary theory and policy which is known as New Keynesian macroeconomic approach, money is implicitly modeled. Nevertheless, McCallum (2008) states that money is required since it is not clear that central banks can control interest rates of macroeconomic importance in a world without monetary aggregates providing its essential functions. In our model, as it is expected, an increase in money supply might result in lower rate of interest. A negative coefficient is anticipated for MONEY variable.

Money demand side in the model is represented by CREDIT and POP variables. An increase in credit demand and population in an economy raises demand for money and accordingly interest rates. At this respect, coefficients of CREDIT and POP are expected to be positive.

ECONGLOB variable is an index of economic globalization. It is constructed on a scale of one to hundred, where hundred is the maximum value for economic globalization. Despite the findings in several studies that relate financial integration with increased macroeconomic volatility, financial integration also provides economies with benefits. Such studies as by Chinn and Fairlie (2010) present empirical evidence that financial openness and integration offer access to international funds more easily and possibly with lower costs. This implies that highly globalized countries can have lower rates of interest. Therefore, a negative coefficient is anticipated for ECONGLOB variable.

Addison and Heshmati (2003) present empirical evidence that ICT has significant positive effect on FDI. Along with financial globalization and integration, FDI inflows are expected to bring about an increase in money supply hence providing a decrease in interest rates. As a result, a negative coefficient is expected for FDI variable.

Before proceeding to evaluate the empirical results, it will be better to check the correlation between two interest rates and four indicators of ICT penetration. Table 2 provides correlation coefficients and probability values (P-values) for each particular variable pairs. As in the table, correlation coefficient values between LENDINRATE variable and four ICT proxies (i.e., INTERNET, CELLPHONE, COMPUTER, and FXBROADBAND) are negative and vary from -0.345 to -0.659 while correlation coefficient values between DEPINRATE variable and four ICT proxies are negative and vary from -0.333 to -0.515. Also all of them are highly statistically significant.

Table 2
Correlation Matrix

	LN.RATE	DP.RATE	INTRNT	C.PHON	COMPT.	FXBR.BND	CRDT	ECO.GLB	FDI	INFL.	MONEY	POP.
LND.RATE	1.0000											
Prob.	-											
DEP.RATE	0.7188	1.0000										
Prob.	0.0000	-										
INTERNET	-0.6531	-0.4728	1.0000									
Prob.	0.0000	0.0000	-									
C.PHONE	-0.3454	-0.3334	0.6021	1.0000								
Prob.	0.0000	0.0000	0.0000	-								
COMPT.	-0.6592	-0.5158	0.8822	0.5158	1.0000							
Prob.	0.0000	0.0000	0.0000	0.0000	-							
FXBR.BND	-0.5184	-0.3633	0.8396	0.6020	0.8341	1.0000						
Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	-						
CRDT	-0.6198	-0.3610	0.5831	0.2264	0.6343	0.6022	1.0000					
Prob.	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000	-					
ECO.GLB	-0.5441	-0.4846	0.5587	0.3630	0.5705	0.3827	0.1970	1.0000				
Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	-				
FDI	0.0263	-0.1615	-0.2056	-0.1798	-0.1723	-0.2907	-0.2888	-0.0185	1.0000			
Prob.	0.7095	0.0213	0.0033	0.0103	0.0140	0.0000	0.0000	0.7937	-			
INFL.	0.3829	0.3351	-0.3044	-0.1547	-0.3048	-0.2480	-0.2782	-0.3053	0.1300	1.0000		
Prob.	0.0000	0.0000	0.0000	0.0275	0.0000	0.0004	0.0001	0.0000	0.0646	-		
MONEY	-0.0889	-0.0632	0.1632	0.0376	0.1495	0.2362	0.3195	0.0880	-	-0.1396	1.0000	
Prob.	0.2074	0.3706	0.0200	0.5943	0.0332	0.0007	0.0000	0.2119	0.1210	0.0470	-	
POP	-0.2118	-0.3296	0.1869	0.2010	0.3142	0.2015	-0.0301	0.4318	0.1850	-0.1277	0.4189	1.0000
Prob.	0.0024	0.0000	0.0076	0.0040	0.0000	0.0039	0.6701	0.0000	0.0082	0.0694	0.0000	-

Results

Table 3 displays estimation results for lending interest rate while Table 4 reports estimation results for deposit interest rate. Each interest rate variable is separately regressed on each ICT penetration indicators.

Table 3

Multivariate Results for Lending Interest Rate

ICT Proxies =>	INTRNT	INTRNT	C.PHON	C.PHON	COMP.	COMP.	FXBR.BN D	FXBR.BND
	FEM	FEM(Driscoll l-Kraay)	FEM	FEM(Driscoll l-Kraay)	FEM	FEM(Driscoll l-Kraay)	FEM	FEM(Driscoll l-Kraay)
ICT	-0.11227	-0.11227	-0.08568	-0.08568	-0.04551	-0.04551	-0.12362	-0.12362
Std. Err.	0.02065	0.02586	0.01058	0.01609	0.01539	0.01210	0.02085	0.03262
Prob.	0.00000	0.00000	0.00000	0.00000	0.00300	0.00300	0.00000	0.00200
INFLATION	0.07331	0.07331	0.20864	0.20864	0.03645	0.03645	0.08237	0.08237
Std. Err.	0.00437	0.01360	0.02535	0.06414	0.01905	0.03860	0.01700	0.03786
Prob.	0.00000	0.00000	0.00000	0.00700	0.05700	0.36400	0.00000	0.04700
MONEY	0.00497	0.00497	0.00371	0.00371	0.00868	0.00868	-0.01539	-0.01539
Std. Err.	0.01777	0.02252	0.01895	0.02743	0.01291	0.01515	0.00958	0.01478
Prob.	0.78000	0.82700	0.84500	0.89500	0.50200	0.57700	0.10900	0.31500
CREDIT	0.04275	0.04275	0.03905	0.03905	-0.02766	-0.02766	0.01905	0.01905
Std. Err.	0.01390	0.01253	0.01196	0.01642	0.01160	0.01736	0.00598	0.00434
Prob.	0.00200	0.00300	0.00100	0.03500	0.01800	0.13700	0.00200	0.00100
ECONGLOB	-0.43257	-0.43257	-0.11221	-0.11221	-0.23092	-0.23092	-0.17105	-0.17105
Std. Err.	0.05457	0.08337	0.06292	0.04292	0.03672	0.07860	0.02766	0.02706
Prob.	0.00000	0.00000	0.07500	0.02300	0.00000	0.01200	0.00000	0.00000
FDI	-0.46831	-0.46831	-0.41393	-0.41393	-0.03810	-0.03810	-0.13769	-0.13769
Std. Err.	0.09286	0.14727	0.08412	0.17727	0.04581	0.04401	0.04644	0.03000
Prob.	0.00000	0.00400	0.00000	0.03800	0.40600	0.40400	0.00300	0.00000
POP	0.00294	0.00294	0.00484	0.00484	0.00157	0.00157	0.00161	0.00161
Std. Err.	0.00211	0.00068	0.00263	0.00180	0.00109	0.00049	0.00113	0.00073
Prob.	0.16400	0.00000	0.06600	0.02000	0.15000	0.00800	0.15500	0.04300
CONSTANT	41.15105	41.15105	20.62012	20.62012	28.79601	28.79601	21.89777	21.89777
Std. Err.	3.65245	6.66054	4.14594	1.95365	2.87855	6.43642	2.05000	1.72018
Prob.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00100	0.00000	0.00000
Num. of obs.	799	799	481	481	285	285	401	401
Num. of countries	86	86	68	68	38	38	57	57
R-sq (within)	0.45850	0.45850	0.36780	0.36780	0.29190	0.29190	0.24220	0.24220
F-statistics	85.38000	33.18000	33.74000	120.11000	14.14000	7.54000	15.39000	87.25000
Prob. of F-stat.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00130	0.00000	0.00000
BPLM-statistics	298.33000		230.15000		212.50000		619.40000	
BPLM-Prob.	0.00000		0.00000		0.00000		0.00000	
Modified Wald-statistics	1.10E+34		1.30E+31		2.20E+30		6.40E+31	
Modified Wald-Prob.	0.00000		0.00000		0.00000		0.00000	
MBDW	0.96610		1.02245		0.67844		0.72935	
BWLBI	1.40142		1.17933		1.38679		1.50167	

Table 4
Multivariate Results for Deposit Interest Rate

ICT Proxies =>	INTRNT	INTRNT	C.PHON	C.PHON	COMP.	COMP.	FXBR.BND	FXBR.BND
	FEM	FEM(Driscoll-Kraay)	FEM	FEM(Driscoll-Kraay)	FEM	FEM(Driscoll-Kraay)	FEM	FEM(Driscoll-Kraay)
ICT	-0.1188707	-0.1188707	-0.0452637	-0.0452637	-0.022359	-0.022359	-0.0620788	-0.0620788
Std. Err.	0.01846	0.01894	0.00726	0.01330	0.01221	0.01396	0.02064	0.02202
Prob.	0.00000	0.00000	0.00000	0.00500	0.06800	0.13500	0.00300	0.01400
INFLATION	0.04550	0.04550	0.10528	0.10528	-0.02018	-0.02018	0.04539	0.04539
Std. Err.	0.00352	0.00930	0.01651	0.03541	0.01439	0.02738	0.01354	0.04059
Prob.	0.00000	0.00000	0.00000	0.01200	0.16200	0.47500	0.00100	0.28200
MONEY	-0.02202	-0.02202	-0.00469	-0.00469	-0.02881	-0.02881	-0.02685	-0.02685
Std. Err.	0.01565	0.01622	0.01617	0.02261	0.01102	0.01446	0.01096	0.00730
Prob.	0.16000	0.18900	0.77200	0.83900	0.01000	0.07000	0.01500	0.00200
CREDIT	0.02218	0.02218	0.03474	0.03474	0.00161	0.00161	0.00042	0.00042
Std. Err.	0.01499	0.01516	0.01055	0.02178	0.00907	0.00778	0.00663	0.00368
Prob.	0.13900	0.15800	0.00100	0.13700	0.86000	0.84000	0.94900	0.91000
ECONGLOB	-0.14502	-0.14502	0.02541	0.02541	-0.16372	-0.16372	0.01677	0.01677
Std. Err.	0.04597	0.06396	0.04228	0.06027	0.02859	0.02573	0.02233	0.02476
Prob.	0.00200	0.03400	0.54800	0.68100	0.00000	0.00000	0.45300	0.50900
FDI	-0.36691	-0.36691	-0.25709	-0.25709	-0.03181	-0.03181	-0.14617	-0.14617
Std. Err.	0.07440	0.10412	0.05599	0.09868	0.03436	0.04508	0.03765	0.02482
Prob.	0.00000	0.00200	0.00000	0.02300	0.35600	0.49400	0.00000	0.00000
POP	0.00227	0.00227	0.00148	0.00148	0.000005	0.000005	0.00016	0.00016
Std. Err.	0.00173	0.00066	0.00171	0.00090	0.00083	0.00025	0.00091	0.00051
Prob.	0.19100	0.00200	0.39000	0.12800	0.99500	0.98500	0.85900	0.75500
CONSTANT	20.22582	20.22582	5.27029	5.27029	18.80634	18.80634	6.38433	6.38433
Std. Err.	3.09312	5.17627	2.72813	2.43662	2.23288	2.72564	1.66315	1.60068
Prob.	0.00000	0.00100	0.05400	0.05100	0.00000	0.00000	0.00000	0.00100
Num. of obs.	755	755	439	439	255	255	357	357
Num. of countries	87	87	66	66	35	35	54	54
R-sq (within)	0.35710	0.35710	0.26700	0.26700	0.21510	0.21510	0.12500	0.12500
F-statistics	52.45000	45.07000	19.05000	22.77000	8.34000	450.15000	6.04000	22.44000
Prob. of F-stat.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
BPLM-statistics	580.66000		165.97000		221.29000		373.66000	
BPLM-Prob.	0.00000		0.00000		0.00000		0.00000	
Modified Wald-statistics	6.20E+33		5.40E+33		1.50E+05		2.50E+32	
Modified Wald-Prob.	0.00000		0.00000		0.00000		0.00000	
MBDW	0.71557		1.07018		0.96121		0.88368	
BWLBI	1.13165		1.22624		1.44081		1.59175	

In the random effect models (REM), differences among countries are captured by a disturbance term ω_{it} which is given by $\omega_{it} = \eta_i + u_{it}$, where η_i is country-specific error term representing unobservable country-specific effects in the model, u_{it} is the combined time series and cross-section error component of the model. In the REM models, it is assumed that η_i is not correlated with any independent variables of the regression model. The Breusch and Pagan Lagrange Multiplier (BPLM) test conducts random effect test. The null hypothesis of BPLM test is that country-specific or time series error variance is zero (i.e., $H_0 : \sigma_u^2 = 0$). As seen in Table 3 and 4, in our analyses the BPLM test rejects the null hypothesis in all models; therefore it is concluded that there are country-specific fixed effects and FEM model is selected.

Once dealing with panel data there are two potential problems that a researcher may encounter, namely heteroskedasticity and autocorrelation. In order to conduct heteroskedasticity test to our FEM models we used

modified Wald test. The null hypothesis of modified Wald test is that country-specific variance is homoskedastic (i.e., $H_0 : \sigma_i^2 = \sigma^2$). The modified Wald test results in Table 3 and 4 rejects the null hypothesis in all models; therefore it is concluded that country-specific variance are heteroskedastic.

On the other hand, if autocorrelation problem exists in the model, then both variances and standard errors are likely to be underestimated and biased, where statistical significances of the estimated regression coefficients are doubtful. Hence we conducted autocorrelation test to our FEM models by utilizing two autocorrelation tests, namely modified Bhargava et al. Durbin-Watson (MBDW) and Baltagi-Wu LBI (BWLBI) tests. The null hypothesis of autocorrelation test is no first-order serial correlation. The values of test statistics can be between 0 to 4 and a value of test statistics close to 2 implies absence of autocorrelation. Since both MBDW and BWLBI test statistics are lower and away from 2 in each model, we accept the alternative hypothesis and conclude that autocorrelation exists.

Once we identified both heteroskedasticity and autocorrelation in our FEM models then we need to re-estimate our FEM model by taking into account heteroskedasticity and autocorrelation problems. Therefore we provide regression results with Driscoll-Kraay standard errors in Table 3 and 4. Also our discussion of the results will rely on the regression results with Driscoll-Kraay standard errors.

Multivariate estimation results taking into account heteroskedasticity and autocorrelation problems indicate the following;

i.) Estimation results using INTERNET as proxy of ICT penetration in Table 3 and 4 imply that:

Coefficients belonging to INTERNET variable are highly significant and get the anticipated negative sign in both models, indicating that ICT penetration in the form of percentage of individuals using the internet seems to decrease interest rate in an economy.

ii.) Estimation results using CELLPHONE as proxy of ICT penetration in Table 3 and 4 hint that:

Coefficients belonging to CELLPHONE variable are highly significant and get the anticipated negative sign in both models, indicating that ICT penetration in the form of mobile-cellular telephone subscriptions per 100 inhabitants seems to lower interest rate in an economy.

iii.) Estimation results using COMPUTER as proxy of ICT penetration in Table 3 and 4 indicate that:

Coefficient belonging to COMPUTER variable is highly significant and gets the expected negative sign in the model using lending interest rate as dependent variable whereas it is insignificant in the model using deposit interest rate as dependent variable. The significant result indicates that ICT penetration in the form of personal computers per 100 people leads to a decrease in interest rate in an economy.

iv.) Estimation results using FXBROADBAND as proxy of ICT penetration in Table 3 and 4 reveal that:

Coefficients belonging to FXBROADBAND variable are statistically significant at least at 5% significance level and take the anticipated negative sign in both models, indicating that ICT penetration in the form of fixed broadband subscriptions per 100 people causes to a drop in interest rate in an economy.

In regard to other determinants of interest rate, the coefficient belonging to INFLATION variable has the theoretically anticipated positive sign and is statistically significant at least at 5% significance level in five out of eight models. Thus, as the inflation rate rises, interest rate goes up in an economy.

The coefficient belonging to MONEY variable takes the theoretically anticipated negative sign and is statistically significant at least at 10% significance level in two out of eight models. According to this, it is weakly supported that as money supply increases, interest rate drops in an economy.

The coefficient belonging to CREDIT variable gets the theoretically anticipated positive sign and is statistically significant at least at 5% significance level in three out of eight models. According to this, it is weakly supported that as money demand in the form of domestic credit increases, interest rate increases in an economy.

The coefficient in front of ECONGLOB variable has the anticipated negative sign and is statistically significant at least at 5% significance level in six out of eight models. Therefore, it is widely supported that as economic globalization increases, interest rate decreases in an economy.

The coefficient in front of FDI variable gets the anticipated negative sign and is statistically significant at least at 5% significance level in six out of eight models. Hence, we say that if FDI level in an economy rises then interest rate lowers.

The coefficient belonging to POP variable has the anticipated positive sign and is statistically significant at least at 5% significance level in five out of eight models. According to this, it is widely supported that an increase in money demand stemming from population increase leads to an increase in interest rate in an economy.

Meanwhile, our primary finding is robust since it keeps its validity regardless of which proxy is used for ICT penetration and interest rate in the models.

Discussion

The world economies, especially the developed ones, are still experiencing the aftermaths created by the last crisis. Problems in economic growth currently dominate the agenda in most countries. Nevertheless, the ICT penetration around the globe has been experiencing an impressive widespread growth. Over two decades prior to the last crisis, the growth rate of labor productivity gain in the US has been attributed to ICT. Though it has reached a peak in developed economies and continues in a relatively steady state, its dispersion still shows an enormous growth in developing economies. This is worth noting because as developing and underdeveloped countries increase their economic performance, their demand for ICT products is expected to grow more rapidly.

Exploring the effects of ICT on interest rates is the motivation behind this study. Yi and Choi (2005) analyze the impact of the Internet on inflation yet, following their work, the literature seems to ignore similar effects of ICT on other macroeconomic or financial variables, particularly on interest rates. This study empirically examines the influence of ICT penetration on interest rates on a cross country sample, and to our knowledge, this is the first study in the literature analyzing the association between ICT and interest rates. In order to test the mentioned association, we employ four different proxies for ICT and two distinct indicators for interest rate in this study. The data are unbalanced data and contain a 24-year period between 1990 and 2013 for various sample sizes with the largest one containing 799 observations of 86 countries.

After controlling for other macroeconomic determinants peculiar to interest rates and taking into account heteroskedasticity and autocorrelation problems in the model, the primary result of the study reveals a strong and statistically significant negative association between ICT penetration and interest rates. This finding keeps its validity across four different proxies of ICT penetration and two distinct interest rates in all models, containing other determinants peculiar to interest rates as control variables. Thus, we may conclude that countries with higher ICT penetration (in the form of percentage of individuals using the internet, in the form of mobile-cellular telephone subscriptions per 100 inhabitants, in the form of personal computers per 100 people, and in the form of fixed broadband subscriptions per 100 people) experience lower interest rates. In addition, our results are robust in the sense that our main finding does not alter regardless of which indicator of ICT penetration and interest rates are used in our models.

Our findings are in line with our prior expectations which are totally the product of economics thoughts. As reported in an ample of studies in related literature, ICT contributes to macroeconomy by increasing productivity through its cost saving aspect. In particular, the results are also in accordance with those of Yi and Choi (2005). These outcomes have important implications for policymakers especially for monetary policymaking authorities. It would be interesting to see the results of similar studies covering the interactions between ICT and other macroeconomic, and financial variables in further research.

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