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Exploring the Nexus Between ICT, Remittances and Economic Growth
A Study of Vietnam

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In this article, we explore the nexus between information and communications technology (ICT), remittances and output per worker in Vietnam from 1980 to 2012. Within the augmented Solow framework, we deploy the autoregressive distributed lag bounds procedure and Granger causality tests to examine the short-run and long-run effects and the direction of causality, respectively. The results show that ICT has a momentous short-run (0.002 per cent) and long-run (0.006 per cent) effect on per worker output. However, in the long run, the elasticity coefficient of remittances is positive but not significant within the 1–10 per cent level of significance, and the short-run results show mixed effects. The causality result indicates bidirectional causation between remittances and output per worker, duly emphasizing their mutually reinforcing effect and a unidirectional causation from capital per worker and ICT to remittances, respectively.

Keywords: Remittances, technology, growth and development, ICT, ARDL bounds test, causality, Vietnam.

I. Introduction

Information and communications technology (ICT) has been one of the cornerstones of growth in many developing countries, particularly due to its ability to support trade, capital flows, communications and mobile transfer services. Remittances are another interesting, albeit controversial, source of growth in developing and emerging economies. In this paper, we explore the nexus between ICT, remittances and income in Vietnam.

Vietnam is an emerging Southeast Asian economy that has experienced decent growth in ICT (Internet penetration) and remittance inflows over the last three decades. Notably, Internet use has superseded more traditional means of communications, such as telephones; relatively cheap Internet services are also readily available in Vietnam's provinces. Furthermore, current World Bank (2013*a*) data indicates that, in terms of remittance inflows, Vietnam is ranked eighth after India, China, Mexico, the Philippines, Pakistan, Bangladesh and Nigeria.

Against this backdrop, we estimate the short-run and long-run effects of ICT and remittances in

Vietnam from 1980 to 2012. In addition, this paper examines the cointegration relationship using the augmented Solow framework (Solow 1956), with insights from growth pioneers (Schumpeter 1933; Domar 1952, 1961; Harrod 1959; Acemoglu 2009; Rao 2010), and the autoregressive distributed lag (ARDL) bounds procedure. We also examine the causality nexus between ICT and remittances. The rest of this paper is set out as follows: Section II provides a brief literature survey on remittances and ICT; section III discusses the paper's framework, the data and econometric method employed, and the estimated results; followed by concluding points in section IV.

II. Literature Survey

II.1 Information and Communications Technology (ICT)

Technology has enhanced productivity and growth (Solow 1956; Romer 1986, 1990; Katz 2009; Minghetti and Buhalis 2010) by lowering the cost of production, streamlining supply chain processes, providing access to information (therefore aiding consumers with decision-making) and providing quality products at competitive prices (Porter 2001; Buhalis and Law 2008). A large body of literature exploring the dynamism in technology expansion, which has proven to be indispensable in the growth and development process, has emerged over the last three decades.

Several studies, particularly those focussing on developed countries, have examined the effects of technology at various levels: firm-industry; national; cross-country; and regional (Mody and Dahlman 1992; Indjikian and Siegel 2005). For instance, at the firm-industry level, Lehr and Lichtenberg (1999) examine firms in service industries in Canada and find that personal computers made a positive contribution to productivity growth. Stiroh (2002) investigates fifty-seven major industries in the United States and finds a strong link between ICT and productivity. Similarly, Brynjolfsson and Hitt (2003) conclude that firms which invested in computer technology are able to realize greater productivity (output per unit of input).[1]

Another strand of literature focuses on the technology-growth relationship using cross-country regression techniques. For instance, Madden and Savage (1998) examine a sample of twenty-seven Central and Eastern European (CEE) countries from 1990 to 1995 and find a positive relationship between investment in telecommunication infrastructure and economic growth. Similarly, Röller and Waverman (2001) use data on twenty-one Organisation for Economic Co-operation and Development (OECD) countries over a twenty-year period (1970–90) and conclude that a positive causal relationship exists between investment in telecommunication infrastructure and subsequent economic performance. Thompson and Garbacz (2007) examine a panel of ninety-three countries from 1995 to 2003 and find that high rates of telecommunication services improve the productive efficiency of the world as a whole and, particularly, in some subsets of low income countries. In addition, Seo, Lee and Oh (2009) analyse a panel of twenty-nine countries and conclude that ICT investment has had positive impacts on GDP growth in the 1990s. In a more recent study, Vu (2011) investigates the effect of ICT on growth for a sample of 102 countries from 1996 to 2005 and finds, *inter alia*: (i) a substantial improvement of growth in the sample period relative to preceding years; (ii) a statistically significant relationship between growth and ICT; and (iii) that personal computers, mobile phones and Internet use have a significant causal effect on growth.

On the other hand, a number of studies argue that the growth effects of investment in technology are inconclusive. Dewan and Kraemer (2000) analysed thirty-six countries from 1985 to 1993 and found that returns from capital investments in ICT, although positive and significant for developed countries, were not statistically significant for developing countries. Jacobsen (2003) analysed eighty-four countries over a ten-year period (1990–99) and found no statistically significant growth effect from computer penetration, although a significant positive link between mobile phones and growth was detected.[2]

II.2 Remittances

Studies focussing on the impact of remittances on economic activities are growing, with particular focus on developing economies. Personal remittances (formerly workers' remittances) are defined here as encompassing personal transfers and employee compensation. Personal transfers include current transfers in cash or in kind received by resident households from non-resident households. Employee compensation includes the incomes of border, seasonal and other short-term workers who are employed in a county where they are not resident, and of residents employed by non-resident entities (World Bank 2013*a*). Remittances have a welfare-enhancing effect, particularly when they support consumption, capital investment, education and human development, entrepreneurship and poverty reduction efforts (Buch and Kuckulenz 2010; Ratha 2007). However, high remittance transfer costs discourage the flow of remittances through formal channels, giving rise to informal money transfers. This is a more pressing issue in developing countries where, besides poor infrastructure, the high cost of transfers constraints the ease of remittances inflows, subsequently compelling remitters to send money via informal channels such as postal mail, through visiting relatives and friends and informal money transfer services (IFTs) (Coxhead and Linh 2010). Formal channels used by remitters often include Western Union money transfers, bank drafts and automated teller machines (ATMs). Notably, remittances inflows are also influenced by a remitter's job stability and the host country's economic performance.

There is empirical evidence to show that remittances have both growth-enhancing and poverty-reducing potential. In a study of seventy-one developing countries, Adams and Page (2005) illustrated that both international migration and remittances significantly reduce the level, depth and severity of poverty in developing countries. In addition, Pradhan, Upadhyay and Upadhyaya (2002) examined the effect of workers' remittances on economic growth in a sample of thirty-nine developing countries using panel data from 1980 to 2004 and a standard growth model; their results indicate that remittances have a positive impact on growth.

Nevertheless, evidence supporting the remittances-led growth (RLG) hypothesis is mixed. Rao and Takirua (2010) examine plausible sources of growth in the small-island economy of Kiribati using the general-to-specific (GETS) technique, and find that remittances have a long-run negative effect. In examining the effects of tourism and remittances in Kenya, Kumar (2013*a*) concludes that the latter has a positive influence on per worker output only in the short-run.

Moreover, while Giuliano and Ruiz-Arranz (2009) find that remittances can boost growth in countries with less developed financial systems, by providing an alternative means of financing investment and overcoming liquidity constraints, Bettin and Zazzaro (2012) argue that the RLG hypothesis is less plausible in countries where the financial system functions effectively. In the same vein, other studies illustrate that, when effectively linked with technology (Philippines) and financial development (sub-Saharan countries), remittances have a positive effect on growth (Kumar 2012; Kumar 2013*b*).

II.3 Remittances and ICT in Vietnam

Vietnam is a member of the Association of Southeast Asian Nations (ASEAN) and is classified as a lower-middle-income country (World Bank 2013*a*). The population was 88.8 million in 2012 and has been growing at an average rate of 1.3 per cent per year over the last two decades. Furthermore, close to 70 per cent of the population resides in rural and suburban areas. Amidst these developments, the economy has experienced an average GDP per capita[3] growth rate of 4.7 per cent (2008–12), with an average per capita of US$853. In addition, over the same period (2008–12), the average inflation rate (measured by GDP deflator) hovered around 14.3 per cent and the unemployment rate stood at around 2.2 per cent of the total labour force. Although net migration numbers have remained negative (implying net out-migration), the rate of emigration has declined by 20 per cent since the late 1970s (World Bank 2013*a*). The United States, Australia, Canada, Cambodia, Germany, France, the Republic of Korea, Japan, the United Kingdom and Thailand are major destinations for emigration.

With regard to technology, the number of Internet users (as a percentage of the population) has risen phenomenally, especially over the last decade. Telephone access was the dominant source of communications from 1980 to 2005, however, since 2000, access to Internet services has grown in leaps and bounds (Figure 1), thanks to the availability of wireless services and easy access to technology products across Vietnam.

Remittances constitute an important source of foreign exchange and external finance (Xiaosong 2005). Notably, overseas development assistance (ODA as a percentage of GDP) has been quite low compared to remittances (as a percentage of GDP). Moreover, unlike foreign direct investment (FDI) inflows (as a percentage of GDP), which have been somewhat volatile, remittance inflows have remained stable and have been growing steadily over time (Figure 2).[4]

In comparison to other financial inflows, remittances comprise 7 per cent of GDP, 90 per cent of FDI, 183 per cent of ODA, and 121 per cent of commercial services exports (Table 1).

As is indicated in Table 2, a high percentage of Vietnamese migrants reside in North America (58 per cent), which is also the largest source of remittances (71 per cent). Moreover, some 15 per cent to 20 per cent of migrants are in Asia and Europe and send close to 2 and 18 per cent of remittances, respectively.

Although remittance transfer costs are gradually subsiding in most source countries, they remain a major constraint to remittance inflows. Recent data (World Bank 2013*b*) shows that sending US$200 and US$500 from the United States costs US$9.77 and US$16.40, respectively. Sending the same amount of money from the Republic of Korea, Australia, New Zealand, Canada and France is relatively more expensive, with France being the most expensive country from which to send remittances to Vietnam (Table 3).

TABLE 1
Remittances Inflows as a Share of Selected Financial Flows and GDP, 2009 (%)

Gross Domestic Product	7
Foreign Direct Investment	90
Official Development Assistance (Net)	183
Merchandise Exports	12
Commercial Services Exports	121

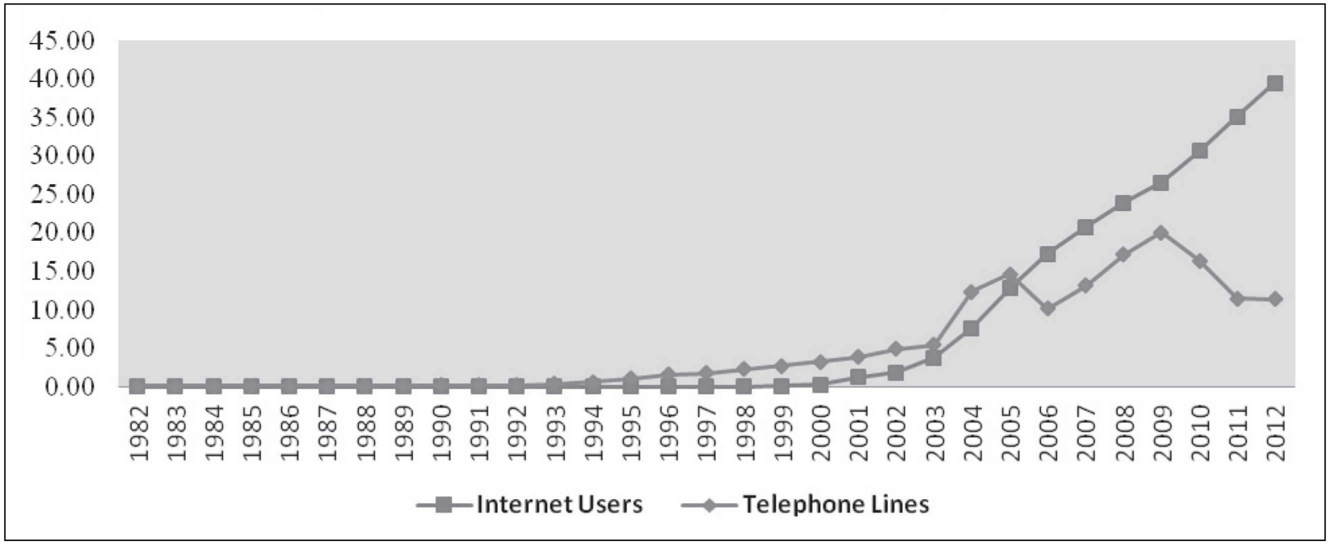
Source: Migration Policy Institute (MPI, 2011).

TABLE 2
Remittances and Migration by Continents

Continent	*Remittance Inflows to Vietnam by Continent of Origin (%)*	*Percent of Vietnamese Migrants by Continent of Destination (%)*
Africa	< 1	1
Asia	2	15
Europe	18	18
Latin America & Caribbean	< 1	< 1
North America	71	58
Oceania	7	8

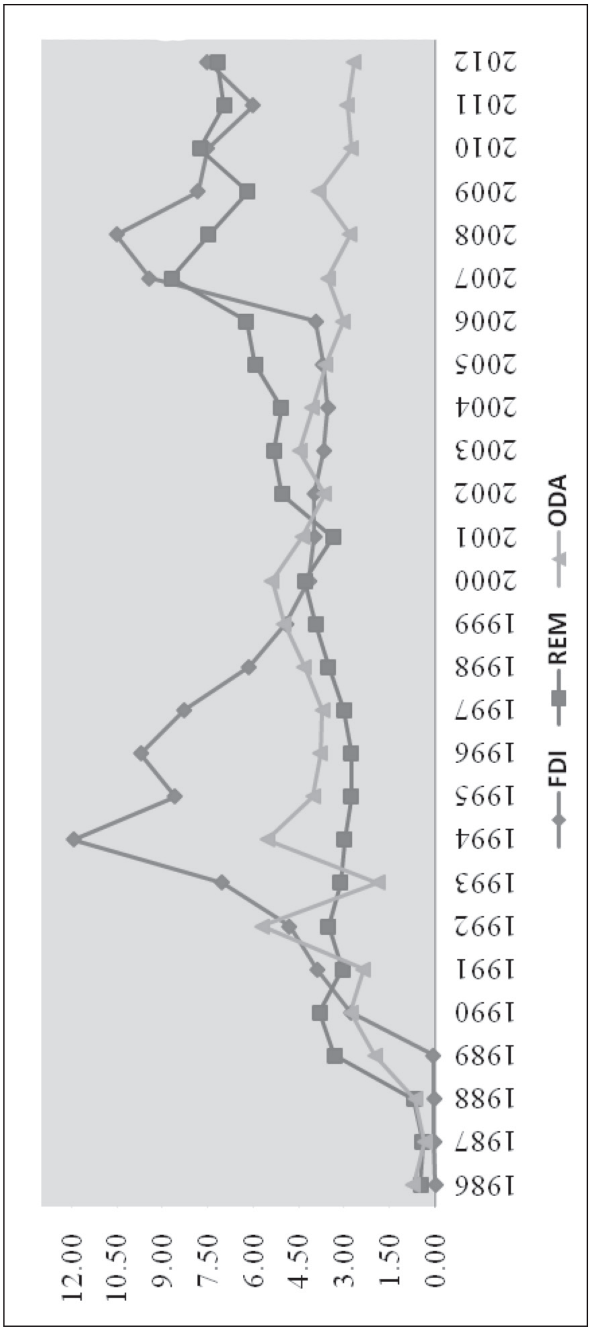
Source: MPI (2011).

FIGURE 1
Telephone Lines vs. Internet Users (% of Population)



SOURCE: World Bank (2013*a*).

FIGURE 2
Remittances, FDI, and ODA (% GDP)



SOURCE: World Bank (2013*a*).

TABLE 3
Average Remittance Transfer Cost from Source Countries

Country	*US$200*	*US$500*
USA	9.77	16.4
Republic of Korea	11.91	16.53
Australia	18.66	26.27
New Zealand	18.96	26.71
Canada	24.84	34.46
France	27.06	35.67

SOURCE: World Bank (2013*b*).

III. Econometric Modelling and Estimation Techniques

III.1 Framework

Using the conventional Cobb-Douglas production function, with the Hicks–neutral technical progress, the per worker output (y_t) is defined as:

$$y_t = A_t k_t^{\alpha}, \qquad 0 < \alpha < 1 \tag{1}$$

Where A = stock of technology, k = capital per worker and α is the profit share. The Solow (1956) model assumes that the evolution of technology is demonstrated by:

$$A_t = A_o e^{gT} \tag{2}$$

Where A_0 is the initial stock of knowledge and T is time.

It is also plausible to assume for our purposes that:

$$A_t = f(LICT_t, LRM_t) \tag{3}$$

Where $LICT_t$, = natural log of Internet users[5] (as a percentage of the population) and LRM_t, = natural log of personal remittances as a percentage of GDP.

Hence, the effects from $LICT_t$, and LRM_t on total factor productivity (*TFP)* can be captured when these variables are entered as shift variables into the conventional production function. Next, we specify the ARDL specifications (see equations (6) to (9) below). Note that each equation has a dummy (*dum*) variable that represents the structural break in the respective level series, identified using the Perron (1997) unit root test with structural breaks. As such, including the dummy variable provides a more robust computation of bound statistics.

$$\Delta Ly_t = \beta_{10} + \beta_{11} Ly_{t-1} + \beta_{12} Lk_{t-1} + \beta_{13} LICT_{t-1} + \beta_{14} LRM_{t-1} + \alpha_{10} dum_y + \sum_{i=1}^{p} \alpha_{11i} \Delta Ly_{t-i} + \sum_{i=0}^{p} \alpha_{12i} \Delta Lk_{t-i} + \sum_{i=0}^{p} \alpha_{13i} \Delta LICT_{t-i} + \sum_{i=0}^{p} \alpha_{14i} \Delta LRM_{t-i} + \varepsilon_{1t} \tag{6}$$

$$\Delta Lk_t = \beta_{20} + \beta_{21} Ly_{t-1} + \beta_{22} Lk_{t-1} + \beta_{23} LICT_{t-1} + \beta_{24} LRM_{t-1} + \alpha_{20} dum_k + \sum_{i=1}^{p} \alpha_{21i} \Delta Ly_{t-i} + \sum_{i=0}^{p} \alpha_{22i} \Delta Lk_{t-i} + \sum_{i=0}^{p} \alpha_{23i} \Delta LICT_{t-i} + \sum_{i=0}^{p} \alpha_{24i} \Delta LRM_{t-i} + \varepsilon_{2t} \tag{7}$$

$$\Delta LICT_t = \beta_{30} + \beta_{31} Ly_{t-1} + \beta_{32} Lk_{t-1} + \beta_{33} LICT_{t-1} + \beta_{34} LRM_{t-1} + \alpha_{30} dum_{tch} + \sum_{i=1}^{p} \alpha_{31i} \Delta Ly_{t-i} + \sum_{i=0}^{p} \alpha_{32i} \Delta Lk_{t-i} + \sum_{i=0}^{p} \alpha_{33i} \Delta LICT_{t-i} + \sum_{i=0}^{p} \alpha_{34i} \Delta LRM_{t-i} + \varepsilon_{3t} \tag{8}$$

$$\Delta LRM_t = \beta_{40} + \beta_{41} Ly_{t-1} + \beta_{42} Lk_{t-1} + \beta_{43} LICT_{t-1} + \beta_{44} LRM_{t-1} + \alpha_{40} dum_{rm} + \sum_{i=1}^{p} \alpha_{41i} \Delta Ly_{t-i} + \sum_{i=0}^{p} \alpha_{42i} \Delta Lk_{t-i} + \sum_{i=0}^{p} \alpha_{43i} \Delta LICT_{t-i} + \sum_{i=0}^{p} \alpha_{44i} \Delta LRM_{t-i} + \varepsilon_{4t} \quad (9)$$

III.2 Data

We used the perpetual inventory method to build the data for capital stock.[6] Data on labour stock was estimated using the average employment rate and population data. A total of thirty-three years of annual data from 1980 to 2012 is used in the analysis. Data on personal remittances (as a percentage of GDP) and Internet use (as a percentage of population),[7] among other key variables, are sourced from the World Development Indicators and Global Development Finance database (World Bank 2013*a*). All variables are transformed into natural logarithmic form before proceeding to the analysis. A descriptive statistics and correlation matrix of the sample data is reported in Table 4.

III.3 Empirical Result

ARDL Bounds Results. The ARDL approach is used because it is relatively simple and recommended for small samples (Ghatak and Siddiki 2001; Pesaran, Shin and Smith 2001). To examine the cointegration based on the computed F-statistics, the use of the critical bounds from Narayan (2005), which are specifically constructed for small sample sizes, is recommended. The critical bounds from Pesaran, Shin and Smith (2001), however, are suitable in cases in which the sample size exceeds eighty. Although one need not test for unit roots in order to investigate cointegration (thus overlooking the order of integration), we emphasize conducting the unit root tests for a couple of reasons:

First, these tests are carried out to ensure that the series are indeed I(0) and/or I(1). This allows for the application of the ARDL bounds procedure instead of other approaches, such as the ordinary least squares (OLS) method, which is not recommended for variables in the presence of unit

TABLE 4
Descriptive Statistics and Correlation Matrix

	Ly	*Lk*	*LICT*	*LRM*
Mean	6.2594	6.6228	–7.3339	0.9295
Median	6.2443	6.5238	–8.9116	1.2136
Maximum	7.1054	7.8335	3.6760	2.1636
Minimum	5.5405	5.7228	–21.4993	–0.9009
Std. Dev.	0.4958	0.6876	8.9308	1.0073
Skewness	0.2250	0.3223	–0.0932	–0.7319
Kurtosis	1.7051	1.7774	1.4563	2.0239
Jarque-Bera	2.5842	2.6265	3.3244	4.2561
Probability	0.2747	0.2689	0.1897	0.1191
Ly	1.000	—	—	—
Lk	0.9982	1.0000	—	—
LICT	0.9774	0.9715	1.0000	—
LRM	0.8702	0.8644	0.8928	1.0000

roots. Secondly, examining the unit root provides information on the maximum lags, which are useful when performing the Toda and Yamamoto (1995) non-Granger causality procedure. Therefore, we use the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests to examine the time series properties of the variables and compute the unit root statistics. Based on these tests, we conclude that all variables are stationary in their first differences (Table 5), thus indicating that the maximum order of integration is one.

Furthermore, we use the Perron (1997) unit root test to determine structural breaks in the series. The presence of structural breaks may influence the bounds F-statistics and, hence, the cointegration results. We find that except for remittances (as a percentage of GDP), all variables in the levels have unit root (Table 6). However, the first difference I(1) series is stationary for all variables, except in the case of capital per worker.[8] Table 3 shows that the structural breaks in the level series are noted in 1999, 2001, 1996 and 1998 for *Ly*, *Lk*, *LICT* and *LRM*, respectively. In the case of the

TABLE 5
Unit Root Tests Results

Variables in log form	*ADF*		*Phillips and Perron*		*KPSS*	
	Level	*First Difference*	*Level*	*First Difference*	*Level*	*First Difference*
Ly_t	–1.6742	–1.9917	–1.9928	-3.4592^{B}	0.1902^{B}	0.2974^{B}
Lk_t	–1.8060	–2.1098	–2.4385	-3.5075^{B}	0.2326	0.6694^{C}
$LICT_t$	0.1974	–1.4034	–0.6427	-4.0870^{A}	0.1240^{B}	0.2461^{B}
LRM	–2.1193	-4.5384^{A}	–2.1911	-4.4396^{A}	0.1399^{B}	0.1105^{A}

NOTES: The ADF critical values are based on Mackinnon (1996). The optimal lag is chosen on the basis of Akaike Information Criterion (AIC). The null hypotheses for ADF and Phillips-Perron tests are that a series has a unit root (non-stationary) and for KPSS, the series is stationary, respectively. A, B and C denotes 1 per cent, 5 per cent and 10 per cent level of significance denotes the rejection (acceptance) of null in case of ADF and Phillips-Perron (KPSS) tests.

TABLE 6
Unit Root Tests with Single Structural Break

Variables	*Level*		*1st Diff.*	
	T-stat	*Break*	*T-stat*	*Break*
Ly	–3.5314[1]	1999	$-5.1164[5]^{C}$	1994
Lk	$-2.5668[1]^{A}$	2001	–1.9375[8]	2007
LICT	–4.5191[2]	1996	$-6.6045[0]^{A}$	1997
LRM	$-6.9053[0]^{A}$	1988	$-8.15830[0]^{A}$	1989

NOTES: Maximum lag length is set at 2. Critical values are obtained from Perron (1997). The null hypothesis is that a series a unit root with a structural break in both the intercept and trend. A, B denotes rejection of null hypothesis at 1 per cent and 5 per cent level of significance.

first difference series, breaks are noted in the years 1994, 2007, 1997 and 1987 for *ΔLy*, *ΔLk*, *ΔLICT* and *ΔLRM*, respectively. We took this information into consideration whilst conducting the bounds procedure. In other words, we set the break period to one in the respective dummy variables in equations (6) to (9). Hence, the bounds F-statistics show evidence of a long-run cointegration when per worker output (Ly_t) is set as the dependent variable, where the F-statistics of 10.3885 exceed the upper critical bound of 7.063 at the 1 per cent level of significance (Table 7). Notably, when we set all other variables (*Lk*, *LTCH* and *LRM*) as dependent variables, the F-statistics do not satisfy the critical bounds, thus confirming a single cointegrating vector.

Once the existence of a long-run relationship is confirmed, the next step is to estimate the long-run and short-run equations. During this process, the diagnostic tests are evaluated based on the initial ARDL model (Table 8). This includes: (i) the Lagrange multiplier test of residual serial correlation: ($\chi^2(1)$= 2.4327); (ii) Ramsey's RESET test using the square of the fitted values for correct functional form: ($\chi^2(1)$ = 2.4327); (iii) the normality test based on a test of skewness and

TABLE 7
Results of Bound Tests

Dependent Variable		*Computed F-statistic*
Ly		10.3885[A]
Lk		1.4067
LICT		2.1032
LRM		0.6990
Critical Value	*Lower bound value*	*Upper bound value*
1%	5.333	7.063
5%	3.710	5.018
10%	3.008	4.150

NOTES: Critical values are from Narayan (2005), "Critical values for the bounds test: case III: unrestricted intercept and no trend", p. 1988; A — indicates significance at 1 per cent level.

TABLE 8
Diagnostic Tests from the ARDL Lag Estimates

Test Types	*LM Version*	*p-value*	*F Version*	*p-value*
(I) Serial Correlation	$\chi^2(1) = 0.1813$	0.670	F(1, 22) = 0.1294	0.772
(II) Functional Form	$\chi^2(1) = 2.4327$	0.119	F(1, 22) = 1.8735	0.185
(III) Normality	$\chi^2(2) = 0.2212$	0.895	Not applicable	
(IV) Heteroscedasticity	$\chi^2(1) = 0.2059$	0.650	F(1, 29) = 0.1939	0.663

NOTES: A, B, and C indicates rejection of null hypothesis of presence of respective test types at 1 per cent, 5 per cent and 10 per cent level of significance, respectively.

kurtosis of residuals: ($\chi^2(2) = 0.2212$); and (iv) the heteroscedasticity test based on the regression of squared residuals on squared fitted values: ($\chi^2(1) = 0.2059$).

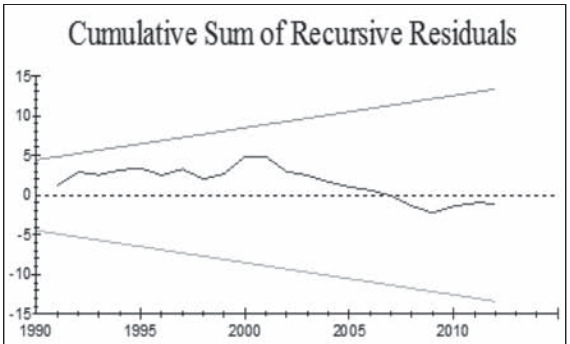
Based on the chi-square results, the diagnostic tests show that the equation performed well. This is because the disturbance terms are normally distributed and serially uncorrelated with homoscedasticity of residuals, thus confirming that the models have correct functional form. Moreover, the cumulative sum control chart (CUSUM) and CUSUM-of-squares plot, which measure the stability of the parameters in the model, indicate that the model is indeed stable (Figures 3a and 3b).

Regression Results. The short-run results (Table 9) indicate growth in output per worker (lagged one period) ($\Delta Ly_{t-1} = 0.9039$), which is a measure of short-run growth policy. They also show that capital productivity ($\Delta Lk_t = 0.2231$) has a positive and statistically significant (at the 1 per cent level) effect on output per worker. The shift variable, i.e., ICT ($\Delta LICT_t = 0.0021$) has a positive and statistically significant (at the 5 per cent level) effect on output per worker. Notably, the coefficient of ICT in the short run is, nevertheless, relatively small. Remittances, on the other hand, have a mixed outcome.

We note that the coefficients of remittances are positive and significant (at the 5 per cent level) ($\Delta LRM_t = 0.0111$) in the current period. However, the coefficients are negative ($\Delta LRM_{t-1} = -0.0187$) in the lag-one period (at the 5 per cent level of statistical significance). Subsequently, the net effect of remittances in the short-run is marginal and negative (–0.0076). The error-correction term ($ECT_{t-1} = -0.3164$), which measures the speed at which prior deviations (errors) from the equilibrium are corrected (approximately 36 per cent), has a correct (negative) sign and is significant at the 1 per cent level — thus indicating a relatively speedy convergence with the long-run equilibrium. It is therefore evident that ICT has a direct positive effect on output per worker in the short-run, while remittances have a mixed effect.

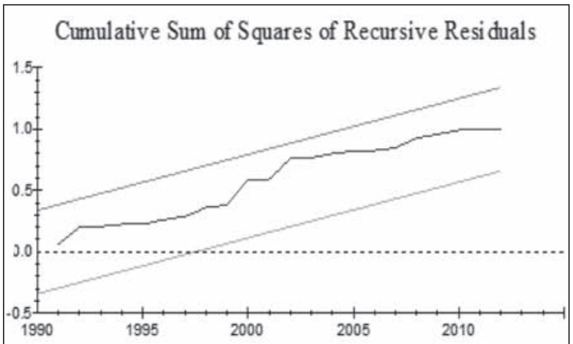
The long-run results show that capital per worker (statistically significant at 1 per cent level) is the dominant driver of growth ($Lk_t = 0.6173$). The capital share (or the coefficient of the capital per worker variable) is relatively higher than the stylized value of 0.33 (Rao 2007; Ertur and Koch 2007). This is plausible when: (i) capital and labour inputs grow at relatively similar rates; (ii) an economy is predominantly developing, hence a large number of self-employed persons derive income from both capital and their own labour (Gollin 2002) thus making it difficult to obtain meaningful measures of income shares; and (iii) the quality of data and the sample size are sound (Bosworth and Collins 2008). Moreover, the elasticity coefficient of ICT is 0.006 per cent ($LICT_t = 0.0058$), which is statistically significant

FIGURE 3a



The straight lines represent critical bounds at 5% significance level

FIGURE 3b



The straight lines represent critical bounds at 5% significance level

TABLE 9
Estimated Long-run Coefficients and Error Correction Representation

Long-run: Dependent variable Ly_t				*Short-run: Dependent variable ΔLy_t*			
Regressor	*Coefficient*	*Standard Error*	*t-ratio*	*Regressor*	*Coefficient*	*Standard Error*	*t-ratio*
Lk_t	0.6173	0.0259	23.7957^A^	ΔLy_{t-1}	0.9039	0.1132	7.9865^A^
$LICT_t$	0.0058	0.0020	2.8405^A^	ΔLk_t	0.2231	0.0579	3.8517^A^
LRM	0.0086	0.0145	0.5978	$\Delta LICT_t$	0.0021	0.0088	2.3638^B^
C_t	2.1750	0.1852	11.7471^A^	ΔLRM_t	0.0111	0.0054	2.0560^B^
				ΔLRM_{t-1}	–0.0187	0.0047	–3.9644^A^
				C_t	0.7861	0.1736	4.5285^A^
				ECT_{t-1}	–0.3614	0.0866	–4.1714^A^

Short-run Dynamics test statistics

R-Squared	.86657	R-Bar-Squared	.82596
S.E. of Regression	.0075617	F-stat. F(6, 24)	24.8949
Mean of Dependent Variable	.049004	S.D. of Dependent Variable	.018125
Residual Sum of Squares	.0013151	Equation Log-likelihood	112.0640
Akaike Info. Criterion	104.0640	Schwarz Bayesian Criterion	98.3280
DW-statistic	2.1293	ARDL(2,0,0,2)	N = 33

NOTES: A, B, C = significant at 1 per cent, 5 per cent and 10 per cent levels of significance, respectively.

at 1 per cent level. In other words, ICT contributes about 0.006 per cent to output per worker in the long-run. With regard to remittances, the coefficient ($LRM_t = 0.0086$) is positive but not statistically significant within conventional levels of significance. Subsequently, from the long-run results, it is clear that capital productivity is the dominant driver of economic growth and ICT supports output per worker, both in the short run and long run, duly indicating its momentous and pervasive role.[9]

The Toda-Yamamoto Approach to the Granger Non-causality Test. Next, we consider the Granger non-causality test proposed by Toda and Yamamoto (1995). The Toda-Yamamoto (T-Y) approach is suitable when the economic series are either integrated at different orders, not cointegrated, or both. In such cases, the error-correction method (ECM) cannot be applied to Granger causality tests and the standard (pair-wise) causality test may not provide robust results. Hence, the T-Y approach provides a method to test for the non-causality hypothesis, irrespective of whether the variables are I(0), I(1) or I(2); not cointegrated; or cointegrated of an arbitrary order. The model used to carry out the Granger non-causality test is presented in the following VAR system, where the series are defined in equations (11) to (14):

$$Ly_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} Ly_{t-i} + \sum_{j=k+1}^{d\max} \alpha_{2j} Ly_{t-j} + \sum_{i=1}^{k} \eta_{1i} Lk_{t-i} + \sum_{j=k+1}^{d\max} \eta_{2j} Lk_{t-j} + \sum_{i=1}^{k} \phi_{1i} LICT_{t-i} + \sum_{j=k+1}^{d\max} \phi_{2j} LICT_{t-j} + \sum_{i=1}^{k} \delta_{1i} LRM_{t-i} + \sum_{j=k+1}^{d\max} \delta_{2j} LRM_{t-j} + \lambda_{1t} \quad (11)$$

$$Lk_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} Lk_{t-i} + \sum_{j=k+1}^{d\max} \beta_{2j} Lk_{t-j}$$
$$+ \sum_{i=1}^{k} \theta_{1i} Ly_{t-i} + \sum_{j=k+1}^{d\max} \theta_{2j} Ly_{t-j}$$
$$+ \sum_{i=1}^{k} \vartheta_{1i} LICT_{t-i} + \sum_{j=k+1}^{d\max} \vartheta_{2j} LICT_{t-j}$$
$$+ \sum_{i=1}^{k} \nu_{1i} LRM_{t-i} + \sum_{j=k+1}^{d\max} \nu_{2j} LRM_{t-j} + \lambda_{2t} \quad (12)$$

$$LICT_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} LICT_{t-i} + \sum_{j=k+1}^{d\max} \gamma_{2j} LICT_{t-j}$$
$$+ \sum_{i=1}^{k} \varphi Ly_{t-i} + \sum_{j=k+1}^{d\max} \varphi_{2j} Ly_{t-j}$$
$$+ \sum_{i=1}^{k} \mu_{1i} Lk_{t-i} + \sum_{j=k+1}^{d\max} \mu_{2j} Lk_{t-j}$$
$$+ \sum_{i=1}^{k} \kappa_{1i} LRM_{t-i} + \sum_{j=k+1}^{d\max} \kappa_{2j} LRM_{t-j} + \lambda_{3t} \quad (13)$$

$$LRM_t = \pi_0 + \sum_{i=1}^{k} \pi_{1i} LRM_{t-i} + \sum_{j=k+1}^{d\max} \pi_{2j} LRM_{t-j}$$
$$+ \sum_{i=1}^{k} \rho_{1i} Ly_{t-i} + \sum_{j=k+1}^{d\max} \rho_{2j} Ly_{t-j}$$
$$+ \sum_{i=1}^{k} \omega_{1i} Lk_{t-i} + \sum_{j=k+1}^{d\max} \omega_{2j} Lk_{t-j}$$
$$+ \sum_{i=1}^{k} \psi_{1i} LICT_{t-i} + \sum_{j=k+1}^{d\max} \psi_{2j} LICT_{t-j}$$
$$+ \lambda_{4t} \quad (14)$$

The null hypothesis of no-causality is rejected when the p-values fall within the conventional 1 to 10 per cent levels of significance. Hence, in (11), Granger causality from Lk_t to Ly_t; $LICT_t$ to Ly_t; and LRM_t to Ly_t imply, $\eta_{1i} \neq 0 \forall i$, $\phi_{1i} \neq 0 \forall i$, and $\delta_{1i} \neq 0 \forall i$, respectively. Similarly, in (12), Ly_t, $LICT_t$ and LRM_t Granger cause Lk_t if $\theta_{1i} \neq 0 \forall i$, $\vartheta_{1i} \neq 0 \forall i$ and $\nu_{1i} \neq 0 \forall i$, respectively. In (13), Ly_t, Lk_t and LRM_t Granger cause $LICT_t$ if, $\varphi_{1i} \neq 0 \forall i$, $\mu_{1i} \neq 0 \forall i$ and $\kappa_{1i} \neq 0 \forall i$, respectively. Finally, in (14), Ly_t, Lk_t and $LICT_t$ Granger cause LRM_t if, $\rho_{1i} \neq 0 \forall i$, $\omega_{1i} \neq 0 \forall i$ and $\psi_{1i} \neq 0 \forall i$, respectively.

Based on the unit root results (Table 5), we observe that the maximum order of integration is 1 (m = 1). From the ARDL estimates, using the Akaike Information and Schwarz-Bayes Criterion (Table 9), we note that the optimal lag length is 2 (p = 2). Hence the maximum lags needed to carry out the non-causality tests is 3 (p+m). Before proceeding to the causality results, it is important to ensure that the inverse roots of the auto-regressive (AR) characteristic polynomials are examined. This ensures that the inverse roots are within the absolute unit boundary. We did this by including relevant instruments. The results of the causality tests are presented in Table 10.

From what follows, the T-Y Granger non-causality results (Table 10), which are based on chi-square (χ^2) values, indicate a bidirectional causation between remittances and output per worker ($Ly \longleftrightarrow LRM$). This emphasizes the mutually reinforcing effect of remittances and income. In other words, remittances cause output per worker, which in turn, causes remittance inflows. Moreover, we note a unidirectional causation from capital per worker to remittances ($Lk \rightarrow LRM$) and from ICT to remittances ($LICT \rightarrow LRM$); the latter emphasizes the pervasive role of ICT in supporting remittance inflows.

IV. Conclusion

In this paper, we set out to explore the role of ICT and remittances in Vietnam over the sample period of 1980 to 2012. We examined the short-run and long-run effects using the augmented Solow framework and the ARDL bounds procedure. The results show that ICT has positive and significant effects both in the short and long run. Remittances have statistically significant mixed results in the short run only. Moreover, the Granger causality

TABLE 10
Granger Non-causality Test

Excluded variable	*Dependent Variable:* χ^2			
	Ly	*Lk*	*LICT*	*LRM*
Ly	—	2.6934	4.44699	17.1997[A]
		(0.4413)	(0.2171)	(0.0006)
Lk	0.3426	—	4.8021	7.7734[B]
	(0.9518)		(0.1869)	(0.0509)
LICT	4.7989	2.3342	—	6.8998[C]
	(0.1871)	(0.5060)		(0.0752)
LRM	8.6686[B]	0.1753	0.7699	—
	(0.0340)	(0.9815)	(0.8567)	
Combined	13.9003	4.2552	9.2309	34.7684[A]
	(0.1259)	(0.8938)	(0.4162)	(0.0001)

NOTES: df = 3; A and B refers to 1 per cent and 5 per cent, level of significance respectively; p-values are in the parenthesis. Significance within 1–5 per cent level indicates presence of causality.

assessment, using the T-Y approach, indicates bidirectional causality between output per worker and remittances. The assessment also reveals that capital per worker and ICT cause remittances.

On the policy front, the use of remittances needs to be reviewed. It appears that remittances, to some extent, contribute to income in the short run only. Hence, further research on the actual use of remittances will provide greater insights to the role remittances play in Vietnam. Nevertheless, channelling remittances into productive capital projects and other income-generating activities are likely to have desirable effects in the long run. The current short-run effect of remittances indicates that they are used to finance consumption expenditure, to a large extent (Pfau and Giang 2009).

In order to increase the long-run effects of remittances, financial products and formal channels through which remittances may be mobilized must be made more cost effective and efficient. Moreover, technology to facilitate mobile remittance transfers and other payment methods should be further developed. Besides improving financial and ICT literacy with regard to remittances, establishing mobile network operation, or MNO-led, services and remittance-linked banking services may help increase competition and reduce the cost of transferring remittances. Exploring remittance-linked deposits and loan facilities (micro-savings, micro-lending, micro-insurance, etc.) will also pave the way for greater financial and technological improvements.

In addition, there is a need for infrastructure development and sound economic institutions that can effectively support the linkages between remittances and ICT, with the latter largely characterized by mobile money transfers and mobile wallet systems. Basic infrastructure enhancements include improvements to transportation services and postal and courier services, with sound regulatory and monitoring institutions to control money whitening and money laundering. As well, overseas Vietnamese workers (OVWs) can be encouraged to send remittances via formal channels and lucrative (investment) deals can be put in place to attract and channel remittance funds into pro-growth and development projects.

Labour mobility, particularly in the case of short-term employment, is gaining ground in many developing countries via bilateral arrangements.

In this regard, Vietnam's migration policies can focus on General Agreement in Trade in Services (GATS) negotiations under Mode IV, which covers the temporary movement of natural persons. Negotiations for short-term and bilateral contracts for OVWs can be undertaken both within and outside the ASEAN region.

In conclusion, pro-growth migration policies and the promotion of ICT use should be important considerations for budgetary and policy decisions. A holistic and broad-based policy view towards scaling-up technology and remittance-transfer services would support sustainable long-run growth and the development of the economy.

NOTES

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1. At the country level, various studies have supported the ICT or technology-led growth hypothesis. These include: Jorgenson and Stiroh (2000), Oliner and Sichel (2000) and Jorgenson (2001) for the United States; Oulton (2002) for the United Kingdom; Jalava and Pohjola (2008) for Finland; Colecchia and Schreyer (2001), Daveri (2002) and Timmer, Ypma and Ark (2003) for the European Union; Jorgenson and Motohashi (2005) for Japan; and Kumar (2012, 2013*b*, 2013*c*) for Sub-Saharan Africa, the Philippines and Vietnam, respectively.
2. However, it can be argued that during pre-2000 periods, technology was relatively less pervasive, particularly in developing countries because technology acquisition, expansion and penetration was significantly low which was further constrained by high cost, lack of literacy, among other things. Consequently, the effect of technology on output remained very low, and in some instances where cost outweighed the benefits, the outcome was negative.
3. In 2005 constant prices.
4. The amount of remittance inflows are dispersed across Vietnam. It is also noted that most of the recipients of overseas remittances are either the elderly, female headed-households or households where the head of the household is unemployed. Remittances are predominantly used for consumption purposes and health expenses (Cox 2004; Pfau and Giang 2009).
5. This is a proxy for ICT penetration.
6. We assumed depreciation rate (δ) of 0.11; initial capital stock (K_0) as 1.2 times the real GDP of 1980 in U.S. 2005 constant dollars. We adjusted the gross fixed capital formation (a proxy for investment, I_t) at 2005 constant U.S. dollars. Hence, $K_t = (1-\delta)K_{t-1} + I_t$.
7. The ratio of Internet users to total population (in percentage) is very close to zero from 1980 to 1995 because Internet and computer technology was in the "infancy" stages of development during this period.
8. In this case, we rely on the ADF, PP and KPSS tests to pursue cointegration tests, however, controlling for the relevant period breaks in the respective series.
9. The trend variable was not significant in both the short-run and the long-run results and did not have any significant influence on the results. Hence, the trend variable was not used in the test.

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