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研究ノート

# Do mobile phones improve per-capita income? Granger causality test based on cross-country dataset*

Akihiko Shinozaki**, Kunio Urakawa***

**Abstract**

The purpose of this study is to examine the impact of mobile technology on global economic development. For this, we used a global dataset that represents the proliferation of cellular phones and per capita GDP among 213 countries and regions. Then, we conducted the Granger causality test to investigate how the rapid spread of cellular phones relates to the growth of per capita GDP by regions, particularly in developing countries, emerging countries, and developed countries during the two decades since the 1990s. This study reveals two observations. First, in the 1990s, higher income led to an early diffusion of mobile technology among developed countries, although no causal relationship was visible in the emerging and developing countries. Second, the worldwide spread of the mobile technology in the 2000s began to promote the growth of per capita GDP not only in developed countries but also in emerging and developing countries such as African nations. Consequently, it seems reasonable to conclude that mobile technology, which prevailed only in the wealthier nations in the 1990s, has turned into a driving force of worldwide economic development in the 2000s.

Keywords: Cellular phone, GDP per capita, Economic development, International comparison, Granger causality test

## 1. Introduction

This study is conducted to assess the effect of mobile phones on economic development, considering its increasing global usage in recent years. The study identifies regional characteristics of the relationship between the mobile phone market penetration rate and income level (GDP per capita) through Granger causality tests of long-term statistical data, which are divided into data of the 1990s and 2000s, of

approximately 200 countries and regions.

Numerous studies have analyzed the economic effect of advancement and rapid increase in the use of information and communication technology (ICT). Although conventional studies have specifically examined the developed countries, where computerization and the use of statistical data have developed quickly, a notable increase in the use of mobile phones began particularly in the developing and emerging countries in the 2000s. Such a trend and its effects have been emphasized in the reports of the UNCTAD and other international organizations.(1) Many studies of the developing and emerging countries, which lagged behind the developed countries in terms of the development and use of statistical data, relied on personal observations through case studies and fragmentary numerical data. Lam and Shiu (2010), however, found a significant effect of the increased use of mobile phones on economic development not only in the developed countries but also in the developing countries, based on analyses conducted using multilateral panel data for the period 1980–2006.

Market penetration of mobile phones in the developing countries became notable during the latter half of the 2000s, which is rather different from the period before the mid-2000s. Shinozaki and Tahara (2014) demonstrated that the use of mobile phones has grown exponentially in many countries and regions since the mid-2000s, irrespective of their education levels (literacy rate) and income levels (GDP per capita). Moreover, results of Gini coefficient measurements have indicated a rapid decline in the digital divide. The progress of global technology transfer, irrespective of income and education standards, suggests the absence of a significant relationship between the mobile phone penetration and economic development on a global scale. On the other hand, many researchers, particularly those examining specific regions such as Africa, have reported a positive effect on economic activities exerted by the rapid increase in mobile phone market penetration, which suggests some relationship between the rapid spread of mobile phones and enhancement of living standards.

Considering such a change, it is necessary to include the period of the latter half of the 2000s in an analysis of the relationship between the diffusion of ICT indicated by mobile phones and economic development indicated by GDP per capita. Thus, this study examines the changes in the relationship and causality between the mobile phone market penetration rate and the growth of GDP per capita from the 1990s to the 2000s to identify the characteristics of the 2000s, when the global usage of mobile phones increased rapidly. It also analyzes the regional differences in the relationship and causality by dividing countries and regions into developed countries, ASEAN countries, BRICS, African nations, transition economies, and others.

## 2. Previous studies

The impact of ICT on economic growth has been examined by a large number of studies since the 1990s. They include country-specific analysis in addition to detailed empirical analysis, particularly in the U.S., based on the growth accounting and production function models. More recently, panel data analysis of

multiple countries, including those of the developing world, has been increasing in response to the sharp growth in mobile phone use.

For instance, the aforementioned Lam and Shiu (2010) examined the relationship between the penetration rates of landline and mobile phones from the 1980s through the mid-2000s (during 1980–2006 for landline phones and during 1997–2006 for mobile phones) and GDP per capita in 105 countries by using the general method of moments (GMM). The results of the Granger causality test indicate a bidirectional causality between landline phones and economic growth in high-income countries, and a bidirectional causality between mobile phones and economic growth in not only high-income but also low-income countries and regions.[(2)]

Moreover, Khuong (2011) analyzed the effects of market penetration of PCs, mobile phones, and the Internet in 102 countries. The study found a positive correlation of PCs, mobile phones, and the Internet with economic growth. The marginal productivity of the Internet was particularly high. The study concludes that ICT contributes to the economic growth because it provides brand new technology and the consequent innovation, improves the way of decision-making in both firms and consumers, and accelerates productivity through cost reduction.

At present, as economic development through the use of ICT is drawing much attention in the international community, the importance of cross-national comparative analysis that includes not only the developed but also the developing and emerging countries has been increasing. Although the mobile phone penetration in the developing countries has been prominent particularly since the latter half of the 2000s, little is known about the economic impact of mobile technology, in which data covers the very period of the late 2000s. This study, therefore, performs the GMM estimation of the causal relationship between the mobile phone penetration and economic growth from 1991 to 2010 by using the global ICT database developed by Shinozaki and Tahara (2014).

## 3. Data and analysis method

### 3.1. Data

The global ICT database includes 213 countries and regions, including special administrative regions such as Hong Kong and Macao added to the 192 member states of the United Nations (as of 2010). It comprehensively covers 142 sets of ICT related statistics and 47 sets of economic and social statistics from 1990 to 2010. Among them, this study employs real GDP per capita (purchasing power parity) and mobile phone penetration rates. The data accommodates approximately twice as many countries and regions studied by Lam and Shiu (2010), which covers 105 countries and regions. Besides, our analysis covers longer period of years from 1991 to 2010 than that from 1997 to 2006 examined by the said study, including the data for the latter half of the 2000s —— a period of rapid change.

In accordance with Urakawa, et al. (2013) and Shinozaki and Tahara (2014), we define 38 countries and

regions, including 34 member states of the OECD, Hong Kong, Taiwan, Singapore, and Macau as "developed countries"; five countries comprising Brazil, Russia, India, China (excluding Hong Kong and Macau), and South Africa are defined as "BRICS"; 17 countries in the former Soviet Union and Eastern Europe excluding Russia and OECD member states are defined as "transitional economies"; nine countries comprising Indonesia, Malaysia, the Philippines, Thailand, Brunei, Vietnam, Laos, Myanmar, and Cambodia are defined as "ASEAN countries"; 52 African nations excluding South Africa are defined as "African nations"; the remaining 92 countries and regions are defined as "developing countries."[3] This study fundamentally follows this regional categorization in the subsequent empirical analysis and compares the results with findings obtained from previous studies.

## 3.2. Model

This study examines the causality between ICT diffusion and changes in income level (GDP per capita) during the 1990s–2000s for each of the above-categorized countries and regions based on the GMM estimation using the dynamic panel data and subsequent Granger causality tests. The following dynamic panel model, which includes a country-specific error factor and lag of the explained variable as an explanatory variable, is specified by Lam and Shiu (2010):

$$GDP_{it} = a_1 + \sum_{m-1}^{M} a_m TEL_{i,t-m} + \sum_{m-1}^{M} c_m GDP_{i,t-m} + \mu_i + \eta_t + v_{it} \quad (1)$$

$$TEL_{it} = a_2 + \sum_{n-1}^{N} b_n GDP_{i,t-n} + \sum_{n-1}^{N} d_n TEL_{i,t-n} + \omega_i + \tau_t + e_{it} \quad (2)$$

where *GDP* in Equations (1) and (2) denotes the natural logarithm of GDP per capita. *TEL* is the natural logarithm of the mobile phone penetration rate. The terms $m$ and $n$ denote the lag level, $i$ stands for the sample country number, $t$ is the sample year, $\mu_i$ and $\omega_i$ are the unobserved country-specific effects, $\eta_t$ and $\tau_t$ are year dummies, and $v_{it}$ and $e_{it}$ are normal disturbance terms.

This dynamic model considers a state-dependence effect because it includes the lagged explained variable as an explanatory variable. In a model that uses such a set of dynamic panel data, the lagged explained variable might correlate with unobservable individual effects (country-specific fixed effects) and prevent from obtaining a consistent estimate from normal estimations. To resolve this problem, Arellano and Bond (1991) proposed the use of GMM estimation, an extended version of the method of moments. Accordingly, this study derives parameters through the GMM estimation based on an equivalent technique.

More specifically, we estimate Equations (3) and (4) that resulted from differentiating Equations (1) and

(2), and by removing country-specific fixed effects $\mu_i$ and $\omega_i$ as follows:

$$\begin{aligned} GDP_{it} - GDP_{i,t-1} = & \Sigma_{m-1}^{M} c_m (GDP_{i,t-m} - GDP_{i,t-m-1}) \\ & + \Sigma_{m-1}^{M} a_m (TEL_{i,t-m} - TEL_{i,t-m-1}) \\ & + (\eta_t - \eta_{t-1}) + (v_{it} - v_{it-1}) \end{aligned} \quad (3)$$

$$\begin{aligned} TEL_{it} - TEL_{i,t-1} = & \sum_{n-1}^{N} d_n (TEL_{i,t-n} - TEL_{i,t-n-1}) \\ & + \Sigma_{m-1}^{M} b_n (GDP_{i,t-n} - GDP_{i,t-n-1}) \\ & + (\tau_t - \tau_{t-1}) + (e_{it} - e_{it-1}) \end{aligned} \quad (4)$$

For the Granger causality tests, based on the parameters obtained in the GMM estimation of Equations (3) and (4), "mobile phone penetration does not affect income level" is established as null hypothesis $H_1$ and "income level does not affect the mobile phone penetration" is established as null hypothesis $H_2$. An F-test is applied for each and an AR test is performed to determine the presence of serial correlation and examine the validity of the estimation results.

## 4. Estimation Results

### 4.1. Results by region for the 1990s

Table 1 presents the GMM estimation results for the period between 1991 and 2000. This table suggests that the causality between the mobile phone penetration and income level during the 1990s is not significant in either direction when observed on a global scale. By region, only the developed countries indicate a significant increase in the mobile phone penetration due to the high income level. It is appropriate to interpret that in the 1990s, the wealth and high income encouraged investment in and use of mobile phones in the developed countries (see Table 1).

On the other hand, no positive correlation was found in regions other than the developed countries. It should be noted that the sign of the coefficient in BRICS is even negative because Russian GDP per capita decreased during 1992–1996 and in 1998 due to a great turmoil after the collapse of the Soviet Union, while a consistent increase in the mobile phone penetration was seen there during the same periods. Similarly, the sign of the coefficient in other developing countries is slightly negative because this regional category includes several oil-exporting nations, where economies were adversely affected by the persistent fall in oil prices in the late 1990s due to the currency crisis in Asia and Russia. Therefore, some special factors could have affected the coefficient's sign of BRICS and other developing countries in the 1990s.

Table 1. Results of causality tests of economic growth and mobile phone penetration (1991-2000)

| | | | Granger-Causality Test | | | AR Test | | | | Result |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | F statistics | p-value | Result | AR(1) p-value | AR(2) p-value | Result | Sargan p-value | |
| All 213 countries and regions | | H1 | 0.85 | 46.4% | × | 0.0% | 2.4% | ○ | 0.8% | No causality |
| | | H2 | 0.81 | 48.6% | × | 0.0% | 60.7% | ○ | 9.0% | |
| 38 developed countries | | H1 | 1.26 | 28.7% | × | 0.0% | 0.1% | × | 0.0% | GDP→MOBILE |
| | | H2 | 3.44 | 1.7% | ** | 0.0% | 2.3% | ○ | 7.9% | |
| 175 developing countries and regions | BRICS(5) | H1 | 0.66 | 58.6% | × | 52.4% | 79.6% | ○ | 44.5% | H2: Negative corelation |
| | | H2 | 7.37 | 0.2% | ** | 12.1% | 38.5% | ○ | 25.3% | |
| | ASEAN(9) | H1 | 0.62 | 60.8% | × | 0.0% | 0.0% | × | 96.5% | No causality |
| | | H2 | 1.54 | 21.9% | × | 2.7% | 6.6% | ○ | 13.3% | |
| | African nations excludint South Africa(52) | H1 | 1.70 | 17.1% | × | 28.0% | 61.8% | ○ | 5.5% | No causality |
| | | H2 | 0.97 | 41.2% | × | 0.1% | 10.1% | ○ | 45.8% | |
| | Transitoin economies (17) | H1 | 0.74 | 54.2% | × | 79.1% | 59.8% | ○ | 85.6% | No causality |
| | | H2 | 0.81 | 50.0% | × | 29.3% | 12.9% | ○ | 90.3% | |
| | Other countries and regions (92) | H1 | 4.45 | 0.5% | ** | 0.3% | 67.4% | ○ | 47.0% | H1: Negative corelation |
| | | H2 | 2.29 | 7.9% | * | 0.2% | 36.5% | ○ | 38.9% | |

Notes: 1. Granger test: Figures with ** and * marks are significant at the 5% and 10% levels, respectively.
$H_1$: "Mobile phone penetration has no causality for economic growth."
$H_2$: "Economic growth has no causality for mobile phone penetration."
2. AR(2)test: Because x is significant at the 1% level, the null hypothesis (error term has no autocorrelation of second order or more) is rejected and the model is not established. Because ○ is not significant at the 1% level, the null hypothesis cannot be rejected and the model is established.

## 4.2. Results by region for the 2000s

In contrast, the estimation results for the 2000s present a completely different picture. The total of lagged explained variable parameters in GMM estimation show positive signs in all categories of regions, implying a positive relationship between mobile phone penetration and an increase in income level. Consequently, the Granger causality tests uncover the global impact of mobile technology on the economic development, or improvement of per capita GDP (see Table 2).

As for the developed countries, there is statistically significant bidirectional causality for the 2000s, while the causality in the 1990s is from the income level to mobile phone penetration. Besides, the ASEAN countries show the causality from the income level to mobile phone penetration like the one found in developed countries in the 1990s, whereas BRICS, African nations, and other developing countries display the causality from mobile phone penetration to increase in the income level. Yet, no clear causality can be confirmed for transitional economies.

As we noted, a large number of case studies have reported a positive effect on economic growth from the use of mobile phones in Africa and other developing countries. It is likely that our estimations

Table 2. Results of causality tests of economic growth and mobile phone penetration (2001-2010)

| | | | Granger-Causality Test | | | AR Test | | | | Result |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | F statistics | p-value | Result | AR(1) p-value | AR(2) p-value | Result | Sargan p-value | |
| All 213 countries and regions | | H1 | 22.24 | 0.0% | ** | 0.3% | 5.5% | ○ | 0.0% | MOBILE→GDP |
| | | H2 | 1.36 | 25.4% | × | 0.0% | 1.2% | ○ | 5.7% | |
| 38 developed countries | | H1 | 18.67 | 0.0% | ** | 1.5% | 27.4% | ○ | 21.1% | GDP⇔MOBILE |
| | | H2 | 5.86 | 0.1% | ** | 16.4% | 13.4% | ○ | 86.1% | |
| 175 developing countries and regions | BRICS(5) | H1 | 2.32 | 9.3% | * | 27.3% | 6.2% | ○ | 7.3% | Mobile→GDP (10% significance) |
| | | H2 | 1.09 | 36.8% | × | 0.0% | 0.1% | × | 17.3% | |
| | ASEAN(9) | H1 | 1.75 | 16.5% | × | 0.0% | 25.7% | ○ | 13.0% | GDP→MOBILE (10% significance) |
| | | H2 | 2.30 | 8.6% | * | 4.7% | 7.1% | ○ | 63.0% | |
| | African nations excluding South Africa(52) | H1 | 8.09 | 0.0% | ** | 21.4% | 59.7% | ○ | 84.1% | MOBILE→GDP |
| | | H2 | 0.89 | 44.9% | × | 0.0% | 9.0% | ○ | 15.3% | |
| | Transitoin economies (17) | H1 | 1.35 | 26.0% | × | 0.1% | 8.3% | ○ | 20.3% | No Causality |
| | | H2 | 2.48 | 6.4% | * | 1.4% | 0.6% | × | 18.4% | |
| | Other countries and regions (92) | H1 | 20.78 | 0.0% | ** | 0.2% | 24.6% | ○ | 22.2% | MOBILE→GDP |
| | | H2 | 6.85 | 0.0% | ** | 0.0% | 0.4% | × | 16.5% | |

Note: See Notes 1 and 2 of Table 1.

empirically verify such reports based on the worldwide dataset spanning two decades since the 1990s. The results demonstrate the importance of detailed analysis, which covers the late 2000s, by region when examining the relationship between the penetration of mobile technology and economic development.

## 5. Conclusion

This study has shown the differences in the relationship and causality between mobile phone penetration and GDP per capita across various regions of the world by dividing the world into developed countries, ASEAN countries, BRICS, African nations, transition economies, and other countries and regions. The study applied the Granger causality tests to identify the characteristics of the 2000s, during which the global penetration of mobile phones was accelerated, and the changes in such characteristics since the 1990s.

The results indicate the following four findings. First, although the causality from a high-income level to mobile phone penetration was observed in the developed countries during the 1990s, no positive causality between the two was found for any other country or region in the 1990s. Second, the developed countries revealed the bidirectional causality during the 2000s, wherein mobile phone penetration promoted a further increase in the income level while simultaneously their wealth encouraged a more

extensive use of mobile phones. Third, the causality in the ASEAN countries during the 2000s showed that higher income affected their mobile phone penetration, similar to the trend found in the developed countries during the 1990s. Lastly, BRICS, African nations, and other developing countries indicated the causality from mobile phone penetration to an increase in their income levels in the 2000s.

During the 1990s, when mobile phones were high-priced luxuries, the causality for wealth was found in the developed countries that encouraged the increased use of such phones. Meanwhile, other countries and regions lagged behind the developed countries in the spread of the mobile phone because they were excluded from such wealth. However, the situation completely changed during the 2000s. The ASEAN countries in the 2000s, having achieved economic growth after overcoming the late 1990s' Asian currency crisis, exhibited the same characteristics as those of the developed countries in the 1990s. The resulting wealth promoted mobile phone penetration, while the developed countries experienced bidirectional causality between wealth and mobile phone penetration in the 2000s. Furthermore, African and other developing countries, where the prevalence of low-priced mass-market mobile handsets proliferated sharply before the countries became wealthier, demonstrated an unprecedented technology transfer effect of mobile phone penetration on an increase in their income level.

## (Notes)

(1) See Spiezia (2011) and The World Bank (2016).

(2) Studies that analyzed the relation between ICT penetration and other variables using Granger causality tests include those by Lee, Gholami, and Tong (2005) and Lio, Liu, and Ou (2011). Lio, Liu, and Ou examined data related to causality between Internet penetration rates and Corruption Perceptions Index for the period between 1998 and 2005 based on data from approximately 70 countries around the world. Their results also suggested the effect of the Internet penetration that would reduce corruption. Lee, Gholami, and Tong (2005) analyzed the causality between investment in telecommunications and economic growth in 20 countries around the world and pointed out that an increase in investment in telecommunications would facilitate economic growth.

(3) In the Information Economy Report of the UNCTAD, some countries such as Romania and Cyprus, which are not OECD members, are categorized as developed countries but South Korea, Taiwan, Mexico, and Turkey are not included among the developed countries.

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