

Causal Relationship between Telecommunications and Economic Growth: A Study of 105 Countries

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Abstract

The main objective of this paper is to study the importance of telecommunications development to economic growth in 105 countries. A dynamic panel data model is applied to measure the causal relationship between telecommunications development and economic growth in different regions and at different income levels for the period 1980 to 2006. The results indicate that there is a bidirectional relationship between telecommunications development and economic growth for European countries and those belonging to the high-income group. For countries in other regions and those at lower income levels, the relationship is in general unidirectional, that is, it runs from economic growth to telecommunications development. These results are consistent with those of previous studies that argue that the impact of telecommunications development on economic growth is greater in countries in which teledensity has reached “critical mass”.

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I. Introduction

Since the 1980s, the telecommunications sector in many countries has been expanding rapidly. The fast-paced growth of telecommunications services can be explained by a number of factors, such as advancements in technology, market liberalization, and privatization. The output of the world's economy has also been growing at a faster rate during the period. In particular, many developing countries and transition economies have experienced rapid growth. Development in telecommunications is considered to be one of the driving forces behind globalization and the rapid growth of the world's economy.

The main objective of this paper is to study the importance of telecommunications development to economic growth in 105 countries. The study covered in this paper is an extension of our previous regional study on China (Shiu and Lam, 2008). A dynamic panel data model is applied to measure the causal relationship between telecommunications development and economic growth in different countries from 1980 to 2006. We investigate whether the development of the telecommunications sector has contributed to economic growth or whether its expansion is simply a consequence of rapid economic growth. The 105 countries covered in the study are divided into different sub-groups based on region and per capita income. We examine any differences in the causal relationship between telecommunications development and economic growth among countries in different regions and at different income levels.

Since the early 1990s, a number of studies have measured the causal relationship between telecommunications development and economic growth. Few of them, however, consider the situation after 1998. In many countries, telecommunications

reform began in 1998 or later. In addition, over the past decade, many countries have also seen explosive growth in mobile communications. Therefore, the results of previous studies do not capture the impact of telecommunications reform or mobile communications on economic growth, and this study is intended to fill the gap.

The sample sizes of many previous studies have also been relatively small, and they have often been restricted to countries in certain regions (e.g., Asia, Africa, or Eastern Europe) or at similar stages of development (e.g., developing countries or OECD countries). In the current study, the sample size is larger, and it covers 105 countries throughout the world. Hence, the results of our analysis are more comprehensive and provide information about the relationship between telecommunications development and economic growth in different countries in different regions of the world.

The remainder of the paper is organized as follows. Section II summarizes previous studies on the causal relationship between telecommunications development and economic growth. Section III discusses the data and methodology used in this study. Section IV reports the empirical findings, and Section V provides conclusions and policy implications based on those findings.

II. Studies on telecommunications development and economic growth

Studies on the effect of telecommunications development on economic growth began in the 1960s. Many of these confirmed a clear, positive correlation between telecommunications and economic growth (e.g., Jipp, 1963; Hardy, 1980; Moss, 1981; Saunders et al., 1994; Lichtenberg, 1995; Greenstein and Spiller, 1996). However, these studies only investigated the relationship between telecommunications and economic growth without looking at the direction of causality.

Other studies have used a structural model to estimate the significance of telecommunications to economic growth by controlling for other important determinants of growth. In general, these studies have found that investment in telecommunications infrastructure is one of the significant factors in the economic growth of a country, alongside with other factors such as gross fixed investment, education, energy, and transportation networks (e.g., Dholakia and Harlam, 1994; Madden and Savage, 1998; Röller and Waverman, 2001; Datta and Agarwal, 2004).

Although telecommunications development has been found to be one of the factors that affect economic growth, its contribution has varied between countries at different stages of development. Röller and Waverman (1996, 2001), for example, examine the impact of investment in telecommunications infrastructure on the GDP of 21 OECD countries and 14 developing or newly-industrialized non-OECD countries between 1970 and 1990 and find that the impact may not be linear: it is greater in OECD countries than it is in non-OECD countries and in countries that have reached “critical mass”, that is, the number of main telephone lines exceeds 40 per 100 persons.

Karner and Onyeji (2007) examine the contribution to economic growth of private telecommunications investment in 14 African countries and 13 countries in Central and Eastern Europe (CEE) for the period 1999 to 2005. Their regression results indicate that the contribution is positive but insignificant. They argue that this may be due to the relatively low level of telecommunications infrastructure in the selected countries, which diminishes the effectiveness of private investment in telecommunications.

The studies conducted by Cronin et al. (1991, 1993a, b) are the earliest attempts to use causality tests to investigate the causal relationship between telecommunications and economic growth. They discover a two-way (bidirectional) relationship between

telecommunications infrastructure and economic growth in the United States. A causality analysis carried out by Madden and Savage (1998) also confirms a bidirectional relationship between telecommunications investment and economic growth in CEE countries. In a more recent study, Dutta (2001) finds that the evidence for causality that runs from telecommunications infrastructure to economic activity is stronger than that for causality in the opposite direction. This pattern holds for all of the 15 industrialized and 15 developing countries being studied.

The results of Chakraborty and Nandi's (2003) study indicate a bidirectional relationship between teledensity and GDP in both the short run and the long run in 12 developing countries in Asia. When these countries are divided into two groups with a high and low degree of privatization, respectively, the causality is bidirectional only for those countries in the former group. For those with a low degree of privatization, the causality runs from teledensity to GDP.

Cieslik and Kaniewsk's study (2004) confirms a positive and statistically significant causal relationship between telecommunications infrastructure and income at the regional level in Poland and finds that the causality runs from the former to the latter. Shiu and Lam (2008) find that there is a unidirectional relationship from GDP to telecommunications development in China. Causality in the opposite direction, that is, from telecommunications to economic growth, is found only in the affluent eastern region, but not in the low-income central and western provinces. A study by Yoo and Kwak (2004) finds a bidirectional relationship between information technology investment and economic growth in South Korea over the period 1965-1998. A more recent study carried out by Wolde-Rufael (2007) also finds a bidirectional relationship between the two in the United States over the period 1947-1996. Table 1 summarizes

the methodologies, data, and results of previous causality studies on telecommunications and growth.

To conclude, the results of previous studies in general indicate either a bidirectional relationship between telecommunications development and economic growth or a unidirectional relationship from the former to the latter. In addition, there are also studies (e.g., Röller and Waverman, 1996, 2001; Karner and Onyeji, 2007) that indicate that the contribution of telecommunications to economic growth is not independent of the level of telecommunications development.

III. Data and Methodology

Data

Data about telecommunications development and economic growth in different countries are required for our causality tests. Following previous studies (e.g., Röller and Waverman, 2001; Chakraborty and Nandi, 2003), we use teledensity (or the penetration rate) as a proxy to measure the development of the telecommunications sector in our study. Teledensity is defined as the number of fixed-line and mobile phone subscribers per 100 persons. In view of the explosive growth of mobile communications in the past decade, we believe that including the number of mobile phone subscribers in our definition of teledensity is a better proxy to reflect telecommunications development in the world. Economic growth is measured by GDP in U.S. dollars at constant (2000) prices, using the purchasing power parity (PPP) exchange rates for currency conversion.

The data used in this study are taken from the databases of the International Telecommunications Union (ITU) and the World Bank (World Development Indicators), which have allowed us to construct a complete dataset of GDP and telecommunications statistics for 105 countries from 1980 to 2006. Because the GDP statistics of many countries are not available for the pre-1980 period, the number of countries covered would be reduced substantially if the study period began any years earlier than 1980. Some figures for mobile phone subscribers are missing in the databases for the early period of our data set.¹ In these cases, we use only the number of fixed-line subscribers to measure teledensity. As mobile communications were not popular in the early introductory stage, having a penetration rate of less than one per 100 persons, the omission of these figures should not have any noticeable effect on the results of our study.

Table 2 lists the 105 countries covered in the study. We divide them into different groups based on region and per-capita GDP (according to the classification of the ITU) to allow us to study the patterns in the causal relationship between telecommunications development and economic growth across different regions and income levels.

Methodology

A dynamic panel data model (see Holtz-Eakin et al., 1988; Arellano and Bond, 1991) is applied to investigate the causal relationship between telecommunications development and economic growth, based on panel data of real GDP and teledensity for 105 countries during the 1980-2006 period. Estimation using panel data not only allows us to have more degrees of freedom than that using time-series or cross-sectional data, but it also takes account of heterogeneity in the responses from countries and their sub-

groups. Furthermore, the use of panel data enables us to control for omitted variable bias and to reduce the problem of multicollinearity among the explanatory variables. Given all of these advantages, more accurate and efficient estimation results can be obtained.²

The dynamic panel data model^{3,4} for examining the causal relationship between telecommunications development and economic growth is as follows.⁵

$$GDP_{it} = \alpha_1 + \sum_{m=1}^M a_m TEL_{i,t-m} + \sum_{m=1}^M c_m GDP_{i,t-m} + \mu_i + \eta_t + v_{it} \quad , \quad (1) \quad \text{and}$$

$$TEL_{it} = \alpha_2 + \sum_{n=1}^N b_n GDP_{i,t-n} + \sum_{n=1}^N d_n TEL_{i,t-n} + \omega_i + \tau_t + e_{it} \quad . \quad (2)$$

GDP and TEL refer to logged real GDP and logged teledensity, respectively, and m and n indicate the levels of lags for these two variables. i represents the countries in the sample, and t represents the time periods. μ_i and ω_i are the unobserved country-specific effects, and η_t and τ_t are the time period dummies. The error terms are represented by v_{it} and e_{it} .

Estimating equations (1) and (2) with OLS is problematic due to the inclusion of the lagged dependent variable as a regressor, because GDP_{it} (TEL_{it}) is a function of the unobserved country-specific effects, μ_i (ω_i), and so is GDP_{it-1} (TEL_{it-1}). Given this correlation of a regressor with the individual effect, biased and inconsistent OLS estimates could be resulted. Therefore, we have to solve the problem by eliminating μ_i and ω_i by first-differencing the above model. In addition, if a variable is found to be non-stationary and have an integration order of 1, then we can ensure stationarity by first-differencing the variable.⁶ Therefore, equations (1) and (2) are estimated in their first-differenced forms:

$$GDP_{it} - GDP_{i,t-1} = \sum_{m=1}^M c_m (GDP_{i,t-m} - GDP_{i,t-m-1}) + \sum_{m=1}^M a_m (TEL_{i,t-m} - TEL_{i,t-m-1}) + (v_{it} - v_{i,t-1}), \quad (3)$$

and

$$TEL_{it} - TEL_{i,t-1} = \sum_{n=1}^N d_n (TEL_{i,t-n} - TEL_{i,t-n-1}) + \sum_{n=1}^N b_n (GDP_{i,t-n} - GDP_{i,t-n-1}) + (w_{it} - w_{i,t-1}). \quad (4)$$

Although we have excluded the country-specific effects⁷ and ensured the stationarity of the variables by first-differencing the two time series, estimation of the above equations still yields biased estimates. This is because first-differencing introduces a correlation between the new error term and the differenced lagged-dependent variable. To deal with this simultaneity problem, we use the Generalized Methods of Moments (GMM) estimator suggested in Arellano and Bond (1991) for our estimation. The general idea is to use lags of the dependent and independent variables in each of the above equations as instruments for the lagged dependent variable. In particular, we consider lags up to four periods to reduce the finite sample biases that result from having too many instruments relative to our cross-sectional sample size (see Alonso-Borrego and Arellano, 1999).

After addressing the econometric problems induced by unobserved individual specific effects and simultaneity in the lagged-dependent variable models, we can apply the dynamic panel data model to the complete panel dataset and to the sub-groups based on region and per-capita GDP. The tests for the non-causality of teledensity to real GDP and real GDP to teledensity can then be conducted using the hypotheses: $a_1 = a_2 = \dots = a_M = 0$ and $b_1 = b_2 = \dots = b_N = 0$. These two hypotheses correspond to $H_1 =$ teledensity does not Granger-cause real GDP, and $H_2 =$ real GDP does not Granger-

cause teledensity. The F test is then carried out for these hypotheses. If the F statistic is greater than the critical value for an F distribution in either H_1 or H_2 or both, then we can reject the null hypotheses and conclude that there is a causal relationship between telecommunications development and economic growth.⁸

IV. Empirical results

Table 3 shows the results of our panel unit-root tests applying the Fisher-ADF and Fisher-PP tests. The test statistics suggest that the levels of the real GDP and teledensity series are non-stationary. After first-differencing the series and reapplying the tests, no sign of non-stationarity is exhibited. We can therefore make the general conclusion that both series are integrated of order 1. Given that both series have the same integration order, we can proceed to an estimation of the dynamic panel data model for the 105 countries between 1980 and 2006. The dynamic panel data model used in this paper has taken neglected heterogeneity and conventional simultaneity into account. Different assumptions of GMM weights and covariance calculations have been made in the dynamic panel data model applied to different sub-groups of countries. The Sargan test of overidentifying restrictions (Sargan, 1958) and tests for first- and second-order serial correlation⁹ in the first-differenced variables have been applied to test for the validity of the instrumental variables and the presence of serial correlation, respectively. The dynamic panel data model used in each sub-group has passed all of these tests.

After ensuring that the panel data models have passed the specification tests, we then proceed to conduct the causality tests or the exclusion restriction tests. The results of the panel causality tests are shown in Table 4.

The dynamic panel data model is first applied to the complete panel dataset (that covers all 105 countries) to examine the overall causal relationship between telecommunications development and economic growth in all of the countries under study. Neither hypothesis H_1 nor hypothesis H_2 can be rejected based on the Wald tests. In other words, there is insufficient evidence to reject the hypothesis that real GDP does not Granger-cause teledensity or the hypothesis that teledensity does not Granger-cause real GDP. This suggests that there is no causal relationship between teledensity and real GDP.

Our results are quite different from those of previous studies, which have either established a bidirectional relationship between telecommunications development and economic growth or a unidirectional relationship from telecommunications development to economic growth. However, as our sample size is much larger and covers countries with different levels of development, it is not very surprising to find that there is no causality between telecommunications and economic growth for the entire sample. It should be noted that although there is no causality for the entire sample, it is still possible to find causality between teledensity and real GDP for individual countries or for individual groups of countries.

After investigating overall causality, we divided the 105 countries into four regions (Africa, the Americas, Asia and Oceania, and Europe) and applied the panel data model to each. The results are totally different from those for the complete panel data. There is now a bidirectional relationship between teledensity and real GDP for European countries. For the other regions, the relationship is unidirectional, that is, it either runs from teledensity to real GDP (for countries in Asia and Oceania) or from real GDP to teledensity (for countries in the Americas and Africa).

We also divided the panel data into four groups based on per-capita GDP (high income, upper-middle income, lower-middle income and low income) and applied the panel data model again to each income group to investigate the causal relationship between teledensity and real GDP. The results indicate that there is a bidirectional relationship between teledensity and real GDP for countries in the high-income group. For the other income groups, the relationship is unidirectional, running from real GDP to teledensity. That means for the countries within these income groups, increased income has led to increased demand for telecommunications services, but a higher level of telecommunications development has not stimulated economic growth.

The results of the causality tests on different regions and different income levels are quite consistent. Of the 31 high-income countries covered in the study, 20 are in Europe. Therefore, it is not surprising to find a bidirectional relationship in European countries and in those belonging to the high-income group. In general, these countries have achieved higher levels of teledensity and real GDP, and the results indicate the mutual precedence of telecommunications development and economic growth.

Our empirical results are also consistent with those of Röller and Waveman (1996, 2001), which finds that the impact of telecommunications infrastructure on economic growth in OECD and non-OECD countries is not linear. Because of network externalities, the impact is larger for those countries that have reached “critical mass”, that is, the number of main telephone lines exceeds 40 per 100 persons. Karner and Onyeji (2007) also argue that a relatively low level of telecommunications infrastructure diminishes the effectiveness of private investment in telecommunications. Hence, it is not surprising to find that a bidirectional relationship between telecommunications development and economic growth only exists for European

countries and for those belonging to the high-income group. Many high-income European countries have already achieved a teledensity reaching “critical mass” 10 years ago.

In sum, our empirical results suggest that an increase in teledensity is more effective in raising income levels in high-income European countries. In less-developed countries or regions, telecommunications development is, in general, caused by an increase in real GDP, but does not itself lead to an increase in real GDP. Considering the results of previous studies (e.g., Dewan and Kraemer, 1998, 2000; Shiu and Lam, 2008), the possible reasons for the lack of income-stimulating effects on telecommunications development in these less-developed countries may be the underdevelopment of the telecommunications infrastructure or other complementary factors. In other words, an improvement in telecommunications infrastructure alone may not be sufficient to stimulate growth. Other complementary factors, such as a good business environment, a well-developed transportation network, a higher level of education, and better training of the workforce, are equally important in the ability of less-developed countries to make the best use of their telecommunications systems to generate income. In the absence of parallel development in these complementary factors, the potential gains from telecommunications development will be limited (Shiu and Lam, 2008).

V. Conclusion and implications

This paper applies a dynamic panel data model to examine the causal relationship between telecommunications development and economic growth. Panel data of 105 countries between 1980 and 2006 are used in the empirical estimation. We control for

country-specific effects and other potential problems associated with lagged dependent variables in the dynamic panel data model,

The overall result of our estimation indicates that there is a bidirectional relationship between real GDP and telecommunications development (as measured by teledensity) for European countries and for those belonging to the high-income group. This implies that in these countries, an increase in real GDP raises the demand for telecommunications services, which, in turn, raises real GDP. In less-developed countries, however, the relationship is, in general, unidirectional, that is, it runs from real GDP to teledensity. These results are similar to those of our previous regional studies on China in which the direction of causality for the affluent eastern region is found to be different from that for less-developed regions.

Our empirical findings support the notion that there is a decoupling of telecommunications development and economic growth in less-developed countries. The rapid growth in the number of telephone subscribers and in telecommunications investment since the 1990s has not triggered a similar growth in real GDP in these countries. The direction of causation sheds light on future telecommunications policies.

The results of our study show that as a country's income level and standard of living increase, the demand for telecommunications services follows suit. However, despite the rapid development of mobile telecommunications networks, teledensity in many less-developed countries and regions remains at a low level and has failed to reach a "critical mass" that can fully exploit network externalities. As our results indicate that there is a bidirectional relationship between telecommunications development and economic growth in countries with higher levels of income and teledensity, the governments of less-developed countries should continue to promote

greater penetration rates for telecommunications services so as to reach “critical mass”. Such a policy may help to increase the real GDP of poor countries and, in the long run, to reduce the income disparity between high- and low-income countries.

Telecommunications development is not found to be an important engine of growth in less-developed countries. The underdevelopment of other complementary factors may be a possible reason for the lack of causality between telecommunications and growth in these countries. This implies that improvement in the telecommunications infrastructure alone is not sufficient to stimulate growth. It is equally important for governments in less-developed countries to develop and enhance other complementary factors, such as the business environment, transportation network, education, and manpower training, to make the best use of their telecommunications systems. In the absence of a parallel development in these factors, the potential gains from telecommunications development will be limited.

In future research, we may develop a structural model that includes the determinants of economic growth other than telecommunications, such as business environment, foreign investment, transportation network, education, and manpower training. By controlling for the effects of these other determinants, we can assess the contribution of telecommunications to the economic growth of different countries. In addition, although the empirical results indicate no overall causal relationship between telecommunications and economic growth for the 105 countries covered in our panel data study, such a relationship may exist for sub-groups of these countries. In future, we may also apply causality tests to individual countries rather than to groups of countries. This task will be time-consuming, but the results will help us to better understand the

patterns of causal relationships between telecommunications development and economic growth in different countries.

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NOTES

¹Data for mobile phone subscribers are missing for the Dominican Republic (1987-89), South Korea (1984-85), Malaysia (1985), the Netherlands (1984), Singapore (1984-87), Spain (1983-85), Tunisia (1985-86), the United Arab Emirates (1980-81), the United States (1981-83), and St. Vincent and the Grenadines (1991).

²See Hsiao [2003] for more details on the advantages of using panel data.

³We need to test whether the series are non-stationary before estimating the dynamic panel data model. According to the classical regression model, the dependent and independent variables in a regression need to be stationary to avoid the problem of “spurious regression.” A spurious regression occurs when a pair of independent series is found to be apparently related according to the standard inference in an OLS regression (see Granger and Newbold, 1974). The presence of non-stationarity can be tested by conducting panel unit-root tests, which determine the stationarity of the variables and the order of integration (see note 3). Both the Fisher-Augmented Dickey-Fuller (Fisher-ADF) (Dickey and Fuller, 1979; Said and Dickey, 1984) and Fisher-Phillips Perron (Fisher-PP) (Phillips and Perron, 1988) tests have been applied to test for stationarity. In both tests, we test the null hypothesis (H_0) that all cross-sections are non-stationary against the hypothesis (H_1) that some cross-sections are stationary (Fisher, 1932; Maddala and Wu, 1999; Choi, 2001). The results of these tests have implications for the specifications of the dynamic panel data model that we are going to apply.

⁴A series is considered to be stationary if it has a constant mean and constant variance, and the covariance is independent of time. If these conditions are violated, then the series is said to be non-stationary. A stationary series has an integration order of 0, whereas a non-stationary time series has an integration order of 1 if first-differencing is required to resume stationarity and an integration order of 2 if second-differencing is required to resume stationarity.

⁵More specifically, this is a dynamic fixed effects panel data model, which takes account of unobservable country-specific effects. The fixed effects model, rather than the random effects model, is used because there are valid reasons to believe that the unobserved country-specific effects, μ_i and ω_i , in equations (1) and (2) are correlated with at least some of the explanatory variables. One example of an unobserved country-specific effect is geographic location, which definitely has an impact on GDP. In the presence of correlation between an unobserved country-specific effect and regressors, the use of a random effects model (which assumes no correlation between the two) will give inconsistent results.

⁶See Anderson and Hsiao (1982) and Lundberg (1985) for more information on the first-differenced specification. In the current context, the estimation of the equations in their first-differenced forms has an extra, appealing intuition in that it enables us to investigate changes in real GDP (economic growth) on changes in teledensity (as a measure of telecommunications development) or the reverse.

⁷In our estimation, we also include time period dummies to take account of time-specific effects. However, we exclude them in the formal presentation of our model for simplicity.

⁸All of the tests and models presented in this paper have been performed and estimated using Eviews software (version 5.1).

⁹An essential assumption for the consistency of the GMM estimator depends on the fact that $E[\Delta\mu_{it}\Delta\mu_{it-2}] = 0$. If this is the case, then we would expect the differenced residuals (i.e., μ_{it} to μ_{it-1}) to display significant negative first-order serial correlation and no second-order serial correlation. The logic of this can be explained as follows. Suppose u_{it} represents the error term for country i in period t . First-order serial correlation in the differenced residuals is given by $E(\Delta u_{it}\Delta u_{it-1}) = E(u_{it}-u_{it-1})(u_{it-1}-u_{it-2}) = E(u_{it}u_{it-1}-u_{it}u_{it-2}-u_{it-1}u_{it-1}+u_{it-1}u_{it-2})$. This would become $E(\Delta u_{it}\Delta u_{it-1}) = -u_{it-1}u_{it-1}$ if there was no serial correlation, i.e., negative first-order serial correlation. In contrast, second-order serial correlation in the differenced residuals is given by $E(\Delta u_{it}\Delta u_{it-2}) = E(u_{it}-u_{it-1})(u_{it-2}-u_{it-3}) = E(u_{it}u_{it-2}-u_{it}u_{it-3}-u_{it-1}u_{it-2}+u_{it-1}u_{it-3})$. With no serial correlation, this would reduce to $E(\Delta u_{it}\Delta u_{it-2}) = 0$.

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Table 1. Previous causality studies on telecommunications development and economic growth

Authors	Methodology	Data used	Results
Cronin et al. (1991)	Granger causality and Modified Sims tests	USA; 1958-1988	Telecoms investment ↔ GDP
Cronin et al. (1993a)	Granger causality and Modified Sims tests	Pennsylvania, USA; 1965-1991	Telecoms investment ↔ employment
Cronin et al. (1993b)	Granger causality and Modified Sims test	USA; 1958-1990	Telecoms investment → aggregate and sectoral productivity growth
Madden and Savage (1998)	Granger causality test	27 CEE countries; 1990-1995	Telecoms investment ↔ GDP
Dutta (2001)	Granger causality test	15 developing and 15 industrialized countries; 1960-1993	Teledensity → per capita GDP Telephones → GDP
Chakraborty and Nandi (2003)	Granger causality test	12 Asian countries; 1975-2000	Degree of privatization: High: teledensity ↔ GDP Low: teledensity → GDP
Cieslik and Kaniewsk (2004)	Granger causality test	Regional panel data, Poland; 1989-1998	Teledensity → retail sales per worker
Yoo and Kwak (2004)	Granger causality test	Korea; 1965-1998	IT investment ↔ GDP
Wolde-Rufael (2007)	Granger causality test	USA; 1947-1996	Telecoms investment ↔ GDP
Shiu and Lam (2008)	Dynamic panel data model	Regional panel data, China; 1978-2004	Overall: GDP → teledensity Eastern/high-income region: teledensity → GDP; Other regions: No causality or GDP → teledensity

Table 2. Sample (105) countries covered in the study

A. By region

Africa (27)	Americas (26)	Asia and Oceania (25)	Europe (27)
Algeria	Argentina	Australia	Austria
Angola	Belize	Bahrain	Belgium
Benin	Bolivia	Bangladesh	Bulgaria
Botswana	Brazil	Bhutan	Cyprus
Cameroon	Canada	China	Denmark
Comoros	Chile	Georgia	Estonia
Cote d'Ivoire	Colombia	Hong Kong, China	Finland
Gambia	Costa Rica	India	France
Ghana	Dominican Republic	Indonesia	Germany
Kenya	Ecuador	Iran	Greece
Lesotho	El Salvador	Japan	Hungary
Madagascar	Grenada	Jordan	Iceland
Mali	Guatemala	Malaysia	Ireland
Mauritania	Honduras	Nepal	Italy
Mauritius	Jamaica	New Zealand	Latvia
Morocco	Mexico	Oman	Luxembourg
Mozambique	Nicaragua	Pakistan	Malta
Niger	Panama	Philippines	Moldova
Rwanda	Paraguay	Saudi Arabia	Netherlands
Senegal	Peru	Singapore	Norway
Seychelles	St. Vincent and the Grenadines	South Korea	Portugal
Sudan	Suriname	Sri Lanka	Romania
Swaziland	Trinidad and Tobago	Syria	Spain
Togo	United States	Thailand	Sweden
Tunisia	Uruguay	United Arab Emirates	Switzerland
Zambia	Venezuela		Turkey
Zimbabwe			United Kingdom

B. By income

Income level	Number of countries
High income	31
Upper-middle income	20
Lower-middle income	28
Low income	26

Table 3. Results of Fisher-ADF and Fisher-PP tests for Real GDP and teledensity

Variables	Fisher-ADF tests		Fisher-PP tests	
	Levels	First differences	Levels	First differences
Real GDP	56.42	977.05*	60.13	1014.76*
Teledensity	133.48	533.10*	38.48	459.36*

H₀: All cross-sections are non-stationary
H₁: Some cross-sections are stationary

Notes: The appropriate lag lengths are selected using the Schwarz information criterion (SIC), and a maximum of up to four lags have been incorporated for the automatic selection of the number of lags in each of the cross-section Fisher-ADF regressions. For the Fisher-PP tests, estimators based on kernel-based sums of the covariances have been used to correct for autocorrelation.

*represents the rejection of the null hypothesis of nonstationarity at the 1% level of significance. We can generally conclude that the series has integration of order 1.

Table 4. Results of panel causality tests from dynamic panel data model for Real GDP and teledensity

Countries	Hypothesis	F-statistics	Result
Complete panel data (105)	H ₁	2.0691	No causality
	H ₂	0.8173	
Region	Hypothesis	F-statistics	Result
Africa (27)	H ₁	0.4481	Real GDP→teledensity
	H ₂	6.9770***	
Americas (26)	H ₁	0.1257	Real GDP→teledensity
	H ₂	2.4524*	
Asia and Oceania (25)	H ₁	2.6774**	Teledensity→real GDP
	H ₂	0.4680	
Europe (27)	H ₁	8.1549***	Real GDP↔teledensity
	H ₂	9.3425***	
Income	Hypothesis	F-statistics	Result
High income (31)	H ₁	3.8504***	Real GDP↔teledensity
	H ₂	3.7039***	
Upper-middle income (20)	H ₁	0.5773	Real GDP→teledensity
	H ₂	6.4810**	
Lower-middle income (28)	H ₁	0.0082	Real GDP→teledensity
	H ₂	4.1261**	
Low income (26)	H ₁	0.6190	Real GDP→teledensity
	H ₂	8.7082***	
H ₁ : Teledensity does not Granger-cause real GDP			
H ₂ : Real GDP does not Granger-cause teledensity			

Notes: The number of countries in each group is shown in parentheses.

***, **, and * indicate the rejection of the Wald tests at the 1%, 5%, and 10% level of significance, respectively.

We have made different assumptions for the GMM weights and covariance calculations in the GMM models. Different lag lengths (maximum of three) for both the teledensity and real GDP levels as instrumental variables have been chosen in the different panel data estimations.

We have tried different specifications of the dynamic panel data models and found that the final results are robust. The results of the AR(1) and AR(2) tests indicate that there are no serial correlations in the estimated models. All of the models passed the Sargan test for the validity of the instrumental variables. The P-values of the AR(1), AR(2), and Sargan tests can be provided upon request.