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Technological Innovation, Market Competition, and Regulatory Reform in Telecommunications

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Abstract In addition to the market and government, technology is believed as the "third hand" in the telecommunications industry, and the "third hand" has played a critical role in the evolution of the telecommunications industry. Thus, it is instructive and meaningful to study the relationship between technological innovation, market competition and government regulation in this industry. Based on this, using a panel dataset for 122 countries over the period of 2010–2015, this study empirically examines the impacts of market competition, independent regulatory agency, and privatization on technological innovation in the telecom industry. In line with some previous literature, the results show that the relationship between technological innovation and market competition in telecommunications is an inverted U-shape. Moreover, this study finds that privatization of telecom operators alone provides few benefits to the effect of innovation, and it is particularly important to build up an independent regulatory body in the privatized telecom broadband market in terms of technological innovation. We also provide several policy implications regarding these findings.

Keywords Telecommunications · Technological innovation · Competition · Regulatory reform

1 Introduction

Traditional economic studies usually fall into a dual paradigm, that is, the different ideas of the "invisible hand" market advocated by the free-market economics school or the "visible hand" government supported by the new Keynesians. However, the characteristics of telecommunications, such as the existence of high sunk costs, result in its typical natural

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monopoly characteristics and usually make this industry form an oligopolistic market. Thus, only using the free market competition mechanism to improve market efficiency may lead to market failure in this special industry [1]. Instead, due to the incomplete information about market conditions, there are great limitations if we use the "visible hand" government to dominate the development of the telecommunications industry, government failure may also occur. For example, as for the Chinese government's mandatory requirements which instructed telecom operators to lift speed and reduce price not long ago, not only consumers not went for it, but also led to the current serious imbalance in market competition. However, despite the above problems, as we can observe, China's mobile communication network has changed from 2.5G to 3G and now to 4G during the past dozen years, and this development process has brought an outstanding price-reducing and speed-lifting effect and achieved continuous improvements in market efficiency. What factor on earth does it lead to the fast growing of this industry in the case where market and government may both fail at the same time? In the analysis of the development course and techno-economic characteristics of the telecom industry, we argue that besides the market and government, there exists a "third hand" in telecommunications: *technology*.

Advancements in telecommunications technology, especially mobile technology, have radically changed people's lives and contributed to productivity growth [2, 3]. The great development of the telecommunications industry in every time is arguably inseparable from the emergence and operation of new technologies. For the telecom industry, technological innovation can bring two effects, one is creating new opportunities for market transitions, such as the transition from telephone voice services to data traffic services; the other is improving the efficiency and quality of services. We believe that the essence of these effects is IT technological progress has directly changed the production tool, which is one of the three essential factors of social productive forces, thus the social productivity is enhanced. Since technological innovation is so important in the evolution of the telecom industry, it is instructive and meaningful to study the impacts of competition and regulation on technological innovation in telecommunications.

Since the mid-1980s, many countries have undertaken a set of regulatory reforms to encourage entry and promote market competition, build up an independent industry regulatory agency and privatize state-owned incumbents. Such regulatory reforms are mainly founded on the basic hypothesis that pro-entry regulation (thus leading to more competition) encourage innovation and investment, whereas such hypothesis stays debatable. Ever since Schumpeter and Arrow proposed their theory, what level of market competition is conducive to innovation has been discussed with great controversy [4, 5]. The tension between Schumpeter's view and Arrow's view is actually related to incentive and ability to innovate [6]. In terms of the incentive to innovate, on one hand, a large business in concentrated markets can expect greater returns on innovation and protect the competitive advantage associated with its innovation because of its larger market share, so the incentive can be positive; on the other hand, a large firm may have less incentive to invest in technological innovation if it can earn substantial profits without innovation and wants to protect the status quo. As for the ability to innovate, a large business in oligopolistic markets is likely to have more working capital and the ability of combining complementary assets to invest in radical technological innovations, which require large-scale and comprehensive R&D. Thus, what kind of market structure is conducive to technological innovation can vary with the industry, market conditions and characteristics of the technology.

Meanwhile, regulatory policies have a direct affect on the innovation incentive of enterprises. In the telecom industry, there are two ways by which regulations mainly may affect innovation activities. First, price regulations, including regulations over retail price and network interconnection fee, can change the profitability of companies, thus changing companies' incentives for innovation. Second, market access controls and price regulations together affect the entry conditions for new entrants, thereby having impacts on the innovation decision-making of potential entrants and incumbents. The existence of an independent regulatory body is an essential factor for effective regulatory governance. The impact of an independent regulatory body on market performance is a hot topic in recent years and has been intensely studied in literature both to telecommunications and other utility sectors [7–9]. The results of these researches, in general, consistently pointed out that one essential institutional factor that affects governance performance is the existence of a powerful and independent regulatory agency, which can make decisions by itself and is accountable to the law rather than to administrative orders. Nevertheless, previous studies rarely focused on the exact impacts of this essential institutional element on telecom innovation.

Several existing literature has studied the relationship between technological innovation (investment) and competition [10–13], or between technological innovation (investment) and government regulation in telecommunications [14–16]. However, although such topic has been studied for many decades, no general conclusion has emerged from these empirical studies. The results of previous theoretical and empirical studies show that the effects of competition and regulation on innovation are ambiguous. Thus, further empirical evidence is necessary to understand this relationship, especially with an up-to-date dataset. Besides, some literature has shown that the success or failure of privatization highly rely on economic and political environments in general and the post-privatization regulatory framework in particular [17, 18]. Thus, the impacts of privatization on technological innovation also need to be examined by further empirical evidence.

Against this background, the purpose of this paper is to explore the role of market competition and regulatory reforms in promoting or postponing technological innovation in the telecom industry. Specifically, we construct a panel data covering 122 countries around the world over the period from 2010 to 2015, and conduct an empirical study of the impacts of competition, independent regulatory agency, and privatization on technological innovation in the telecom industry. In addition to the effect of privatization by itself, we also study its interactive effect with the independent regulatory agency and the degree of market competition in order to unravel the complicated privatization effects and comprehend the essence of privatization.

This study will proceed as follows. Section 2 outlines the empirical framework, including the data, variables and econometric model. Then the empirical results are reported and discussed in Sect. 3. Finally, in the last section, we conclude this study and provide some policy implications.

2 Data and Econometric Model

2.1 Data and Variables

The dataset used in this study is an annual panel composed of about 122 countries covering a period of six years from 2010 to 2015. The panel dataset includes adequate information

on telecom performance indicators, telecom market conditions, regulatory reform variables, and several important national macro data to carry out an empirical study, specifically, to explore the impacts of market competition, privatization, and independent regulatory agency on telecom innovation. The data is collected from a variety of databases, mainly coming from the International Telecommunication Union (ITU), the World Bank Database (WBD) and the World Economic Forum (WEF). Other sources of data contain the World Bank's World Development Indicators (WDI) and the OECD Communications Outlook (OECD-Outlook). OECD-Outlook and WDI are used to check the consistency of data and to fill the missing values.

The goal of our study is to explore the impacts of market competition and regulatory reform variables on technological innovation in the telecom industry. However, how to select the suitable proxy variable which can measure innovation activity and technological diffusion is debated in literature for a long time. Some literature takes the number of patents or the R&D investment as the proxy to measure technological innovation, but such measures are not easy to obtain for a certain sector, such as the telecommunications sector. As for this study, we use the fixed-broadband subscriptions (per 100 people) as the proxy variable for telecom innovation on which the impacts are examined. This index measures the whole internet access subscriptions at high downstream rates by various Internet technologies which include digital subscriber line, fiber-to-the-building, fiber-to-the-home, cable modem, terrestrial fixed wireless broadband, satellite broadband etc. A number of previous researches also regard this indicator as the best proxy variable for telecom innovation [15, 19, 20]. The popularity of this measure can be explained by three reasons: (1) Since this measure shows the whole demand for broadband Internet access in a given country throughout a certain year, this measure is positively related to investment in broadband infrastructures. (2) Technological innovation also includes the process of technology diffusion, which is directly measured by this indicator. (3) As indicated above, in contrast with other measures, this measure is easier to be collected by regulatory agency or national statistics department.

The explanatory variables include (1) a variable which describes the level of market competition for Internet access services on a 0-2 (highest) scale; (2) an independent regulatory agency dummy which equals one in case the country has a separate telecommunications/ICT regulatory body that is independent from the operators and any other governmental bodies in terms of finance, structure, and decision making, and equals zero otherwise; (3) a privatization variable that indicates whether the dominant operator in this country is a public or private entity (the value equals two if the dominant operator in this country is 100 percent private, either due to originally private when created or a privatization; equals one if the dominant operator is a partially private operator which has a portion of its shares sold to a private company, whereas the government still remain one of its shareholders; and zero value refers to a fully state-owned operator which has remained 100 percent government-owned. We also collect several control variables which indicate the characteristics of a given country's macro conditions, which are the per capita GDP and the population size.

2.2 Econometric Model

In line with existing empirical researches, telecommunications performance is a function of variables of interest and some other control variables. Additionally, the model used in this study also consider the following points: (1) Non-linearity of the relationship: Some studies indicated that there is a non-linear relationship between market competition and

telecommunications performance. Following some previous empirical studies, this study assumes that such non-linear part corresponds to the quadratic form of competition indicator. (2) The effects of privatization alone were inconsistent or unclear in the previous literature, so in addition to considering the effects of privatization, we also examine two interaction effects—privatization interacted with competition level and with independent regulatory agency. (3) The cross-country effect: biased results can be obtained as result of individual heterogeneity, and panel data methodology has better ability to control for individual heterogeneity and make less collinearity among the variables. Therefore, the dummy variables for countries are included to consider the presence of individual fixed effects. (4) The time effect: telecom performance variables may change year by year for each country, hence, we also include year dummy variables to consider the existence of temporal effects. (5) Dynamic nature of telecom innovation: following several econometrics studies such as [16, 20], we also take into account the dynamic effect of innovation in telecommunications (take broadband penetration as the proxy variable) via introducing delayed dependent variable in our specification.

Consequently, the model specification used for this empirical analysis finally takes the following form:

$$TII_{it} = \alpha_0 + \beta_1 TII_{i(t-1)} + \beta_2 Comp_{it} + \beta_3 Comp_{it}^2 + \beta_4 Indep_{it} + \beta_5 Prv_{it} + \beta_6 itcCompP_{it} + \beta_7 itcIndP_{it} + \delta C_{it} + u_i + r_t + \varepsilon_{it} \quad (1)$$

where TII_{it} refers to the telecommunications innovation indicator in country i at year t, which is measured by the fixed broadband subscriptions in natural logarithm form in this study. The reason for the natural logarithm transformations of the continuous variables is to avoid probably stationary series problems [21]. $TII_{i(t-1)}$ refers to the delayed dependent variable (by one year). $Comp_{it}$ refers to an indicator which measures the level of competition of internet access service. As mentioned above, some existing researches indicated non-linear relationship between competition and market performance [22, 23], so we also introduce the quadratic form of competition indicator, $Comp_{it}^2$. $Indep_{it}$ and Prv_{it} represent independent regulatory agency dummy and privatization dummy, respectively. As mentioned above, we also consider two interaction effects of privatization, $itcComP_{it}$ and $itcIndP_{it}$ refer to privatization interacted with competition level and with independent regulatory agency, respectively. Moreover, other factors which may affect innovation activities are expressed in the vector of control variables C_{it}, which include the population size and the per capita GDP, both expressed in the natural logarithm form. α_0 represents the intercept, and the error term u_i, r_t, and ε_{it} capture country fixed effects, time fixed effects, and the variation of telecom innovation which is not exactly contained in this model, respectively.

Existing literature got opposite empirical results regarding the relationship of telecom innovation, market competition and government regulation, which may be affected by the econometric techniques. A number of empirical works [19, 24–26] have indicated that several methodological issues need to be addressed when analyzing the impacts of competition/regulation on telecommunications innovation. First, the collinearity problem of the model needs to be examined. The variance inflation factor test can be deployed to check multi-collinearity among the explanatory variables, and its result has indicated the collinearity problem is not present. Second, while the simple ordinary least squares (OLS) method is able to offer instructive insights, several econometric problems may exist in estimating the relations when using the usual OLS, the model needs to address endogeneity bias since telecom performances including broadband deployment may have reverse

effects on competition, and the competition measure may be related to the error term. To deal with this issue, deploying instrument techniques such as the generalized method-of-moments (GMM) or two-stage least squares (2SLS) methods is necessary. Notice that 2SLS method can be equal to GMM method in case the number of endogenous variables is identical to the number of instrumental variables (IVs). However, 2SLS method is less efficient than GMM method in case the number of endogenous variables is less than the number of IVs and heteroskedasticity exist. In this estimation, therefore, we use GMM approach and choose the fixed-broadband sub-basket variable, which is the cost of the subscription to a basic broadband plan per month, as our IV. In particular, we employ GMM continuously updated estimator (GMM-CUE) and two-step generalized method-of-moments (2S-GMM) to estimate the model. Third, instead of random effects (RE), fixed effects (FE) should be used for this model. Using RE or FE estimators is a necessary choice in the panel data regression analysis. In general, RE can produce smaller standard errors than FE, thus RE is generally more efficient. But RE can be inconsistent if the hypothesis that the vector of independent variables are unrelated to the country-specific fixed effects fails [27]. The results of the Hausman tests show the conditions needed for using the RE estimator do not hold, which indicates the FE estimator is preferred to the RE estimator in this analysis.

3 Empirical Results

In this section, we start by presenting our empirical results, and then we discuss and compare the results with results of previous empirical studies. Results from regression based on Eq. (1) are reported in Table 1. The results of 2S-GMM and GMM-CUE are both reported in the table.

As is shown in Table 1, the results do not diverge systematically between the two estimation approaches. And the results are, in general, in consistence with findings of the previous studies. The coefficients of the lagged dependent variables are positive and highly significant (at 1% level) across the two approaches. This finding implies that broadband investment is a long-term adjustment process, and the positive sign shows that the higher the broadband subscription in the previous year, the higher its variation this year. It is consistent with previous empirical researches which consider the dynamic effects [19, 20, 25, 26, 28].

The market competition coefficient is positive while the coefficient of its square is negative, and both coefficients are significant at 1% levels, which suggest that the competition-innovation relationship in the telecom industry should be an inverted U-shape. This finding can be interpreted mathematically as the following: For the low level of competition, competition is positively correlated with technological innovation, while for the high level of competition, competition is negatively correlated with technological innovation. This finding support both the theoretical and empirical results on inverted U-shape relations between innovation and competition conducted by previous researches [22, 29, 30]. Following the interpretation of [30], the result of the inverted U-shape relations can be explained as follows: Competition may lower the profits of companies, so companies want to escape from competition through innovation in order to increase their incremental profits (escape-competition effect). However, competition may also prevent companies from defending their innovation gains, thereby reducing their innovation

Table 1 Estimation results by 2S-GMM and GMM-CUE approaches

Explanatory variable	2S-GMM	GMM-CUE
Ln(fixed broadband subscriptions)$_{t-1}$ (TII_{t-1})	0.349***	0.384***
	(0.087)	(0.068)
Market competition (*Comp*)	0.687***	0.712***
	(0.238)	(0.216)
Square of market competition ($Comp^2$)	− 0.044***	− 0.049***
	(0.017)	(0.016)
Privatization (*Prv*)	0.189	0.121
	(0.546)	(0.475)
Independent regulatory agency (*Indep*)	0.215**	0.284**
	(0.184)	(0.152)
Privatization interacted with competition ($itcComP_{it}$)	0.322*	0.387
	(0.145)	(0.138)
Privatization interacted with independent regulatory agency ($itcIndP_{it}$)	0.487***	0.546***
	(0.201)	(0.182)
Ln (GDP_{pc})	1.354***	1.397***
	(0.478)	(0.469)
Ln (population)	1.128*	1.132**
	(0.364)	(0.362)
R-squared	0.874	0.852

Note: Standard errors in parentheses

***, ** and * denote significance at 1%, 5% and 10%, respectively

incentives (Schumpeterian effect). These two effects coexist and vary for different levels of competition, resulting in an inverted U-shape relationship.

Although there is a positive effect associated with privatization, the effect of privatization is not significant. Nonetheless, the interaction effect between privatization and independent regulatory agency is positively related to telecom innovation and is significant at 1% level. By contrast, the interaction effects of privatization and market competition level are associated with less significant coefficients in both two approaches, suggesting that to promote broadband deployment, it may be not needed for telecom operators to be privatized. This result challenges the traditional idea that private ownership can be better than public ownership in case competition is effective [31]. As for the effects of independent regulatory agency, an independent regulatory agency is positively related to broadband penetration (significant at 5% level). And the highly significant (at 1% level) and positive effects of independent regulatory agency interacted with privatization also suggest that compared to the direct effects of independent regulatory agency on broadband penetration, its facilitating effects in a privatized market are very important.

As expected, the results also show that the logarithm of per capita GDP is positively and significantly correlated with the broadband penetration. This finding indicates the significance of the contribution of national income in improving broadband deployment. The coefficients of the logarithm of the population size are positive and significant, suggesting that the population size is another essential contributory factor of broadband deployment. That is to say, higher population size, in general, can improve the broadband subscriptions.

This result on the strong positive correlation between broadband deployment and population size supports the finding of some previous related studies [19, 32].

4 Conclusion

This study sets out to examine the impacts of market competition, independent industry regulatory agency and privatization on technological innovation in telecommunications, using a panel dataset for 122 countries from 2010 to 2015. According to the estimation results, we get the following conclusions: (1) There is an inverted U-shape relationship between technological innovation and market competition in the telecom industry. This finding shows that when the level of market competition is low, competition is associated with improved telecom performances, however, after certain level of competition, the effects of entrants are diminishing and too much competition can finally have negative impacts on telecom innovation. In other words, excessive competition may result in less incentive to innovate, invest and upgrade service quality because of less profitability of new services. (2) The independent regulatory agency is positively related with telecom innovation, which provides evidence to support the view that the independent regulatory agency is not only a significant institutional factor for good regulatory governance, but also an important contributory factor of technological innovation in the telecom industry. (3) Privatization alone provides few benefits to the effect of technological innovation, results show that even with a certain degree of market competition, the impact of privatization on telecom innovation is still not significant. However, when privatization is complemented by an independent regulatory agency, the effect of privatization turns to positive and significant, which indicates that the function of an independent regulatory agency is especially important in the privatized telecom broadband markets.

Overall, the findings of this study shed new light on public policy and telecom regulation. First, the findings suggest that the conviction of some policymakers that more competition (result from stringent pro-entry regulation) is a prerequisite for promoting technological innovation needs be revisited. In the telecom industry, only a proper competition level (neither over-competitive nor inadequate) is best in terms of technological innovation, regulators and policymakers should introduce and implement moderate regulatory policies so as to promote telecom innovation. Second, although a number of previous studies have indicated that privatization of telecom operators alone may fail to improve market performance, there is still a worldwide tendency in the direction of mass privatization in telecommunications. For instance, China Unicom recently has been partially privatized by conducting the mixed ownership reform. In such condition, accordingly, it is essential to build up a formal independent regulatory authority for the telecom industry.

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