Access Regulation, Competition, and the Investment of Network Operators in the Mobile Telecommunications Industry

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Abstract

Introduced in the mobile telecommunications market across world, mobile virtual network operators (MVNOs) are considered an effective way to promote competition. However, possible adverse consequences for infrastructure investment of mobile network operators (MNOs) create concern. In this paper, we investigate the economic effects of MVNOs and the related regulation on MNO investment behavior. Employing firm-level data across 21 Organisation for Economic Co-operation and Development (OECD) countries, we also look at market efficiency to assess empirically the outcomes of MVNOs and regulation. We find that access regulation leads to investment disincentives for MNOs and that voluntary provision of access may create disincentives as well. Therefore, to improve both market and dynamic efficiencies, regulation needs to be directed at MNO investment incentives.

Keywords: access regulation; mobile telecommunications; MVNO; MNO; investment; competition

JEL classifications: L59, L96, D43, L13

1. Introduction

Competition in mobile telecommunication markets continues to be an important policy issue. National policy makers aim to improve consumer welfare and accelerate network investment by fostering a more favorable environment for competition in these markets. Government policy in this regard is made difficult by the limited radio spectrum and the large investment in networks required for new mobile operators to enter the market.

In the last few decades, some national regulatory bodies have allowed mobile operators that do not own a frequency on the radio spectrum to lease the network facilities of mobile network operators (MNOs). These new mobile operators are referred to as "mobile virtual network operators" or "MVNOs." The nature of MVNOs differs across countries due to the various market characteristics and regulatory parameters of each nation. The International Telecommunications Union (ITU) (2001) defines an MVNO as "an operator that services mobile communications to subscribers without its own airtime and licenses granted by the government." Ovum (2000) characterized them as carriers providing customers with mobile services, issuing independent subscriber identity module (SIM) cards with an independent mobile network code, and operating a mobile communications switch without their own bandwidth. More generally, MVNOs operate with diverse business models ranging from simply reselling network operator services to offering their own services with core network facilities.

Ergas et al. (2005) summarized the rationale of providing mandatory MVNO access to the mobile telecommunications market as follows. First, MVNOs may boost competition in retail markets so that prices of mobile services fall. Due to fiercer competition, mobile penetration accelerates and the quantity of services supplied increases. These outcomes rely on the two conditions. On the one hand, MVNOs would be able to compete against MNOs by offering innovative services that MNOs would not provide to users or by setting cheaper prices than MNOs offer for mobile services. On the other hand, MNOs would invest in downstream innovations in response to the aggressive marketing of MVNOs. Second, services-based entrants to the market that offer new services would avoid the heavy network investment by leasing an incumbent's network. These entrants may eventually invest in building their own infrastructure after having gained sufficient customer bases. This latter rationale is based on the "ladder of investment" or "stepping stone" hypothesis (Cave and Vogelsang, 2003; Cave, 2006; Bourreau et al., 2008).[1]

To some extent, policies on MVNOs seem to have accomplished some of their objectives. In countries where service-based operators have long been established, mobile bills have become more affordable and new services have been offered; i.e. MVNOs appear to have had a positive influence on competition (European Regulators Group, 2006). The service-based entrants have also been instrumental in aggressive price competition (Informa, 2005; NCB, 2005; Ovum, 2005). For example, in Denmark, competition in terms of retail prices intensified after MVNOs entered the market (Ovum, 2005). In general, and in Europe in particular, intensified competition has led to lower prices through entry of new mobile operators and an increase in the number of operators.

[1] Some researchers are critical of this hypothesis, for example, see Hausman and Sidak (2005) and Waverman et al. (2007).

Similar to MVNOs in the mobile market, a vigorous debate about unbundling rages in the Internet market. The experiences and lessons from unbundling illustrate the advantages and disadvantages of access regulation. Two reasons explain decreased MNO investments when MVNOs access MNO networks: externalities of investment (Foros, 2004; Kotakorpi, 2006) and asymmetric risk sharing.

First, MNOs that provide access to MVNOs lose a part of the benefits from any quality improvement of their investments. In other words, mandatory provision of MVNO access can induce spillovers that affect MNO incentives to adopt new mobile technologies or improve their existing networks. MVNOs can take advantage of such spillovers to design or improve their own services, and thereby they expand their market share at the expense of MNOs. The MNOs cannot appropriate all the rents from their investments. Therefore, access regulation undermines MNO incentives for investment and results in lower MNO investment (Foros, 2004; Woroch, 2004; Kotakorpi, 2006).

Second, access regulation involves asymmetric risk sharing between the MNOs that provide access and MVNOs (Pindyck, 2004; Guthrie, 2006). Investment in network infrastructure is largely irreversible, and investing firms generally expect payoffs on the risks associated with irreversible investments in physical capital. However, access regulation allows MVNOs to enjoy smaller risks. When they expect the market to be favorable for the mobile technologies or services that MNO investments make feasible, MVNOs will gain access to an MNO network and compete for market share. This MVNO access lowers returns for MNOs. However, when the market is unfavorable, MVNOs will not participate and MNOs will bear all the risk related to uncertainty. Overall, access regulation lowers the expected payoff to MNOs for their investment, which in turn may reduce their incentives to invest (Pindyck, 2004).

In this paper, we assess the outcome of access regulations since they were implemented about a decade ago in many countries. First, from the perspective of dynamic efficiency, we examine the impact of MVNOs and access regulation on MNO investment intensity. More specifically, we investigate whether regulated access provision affects MNO investment incentives and whether competition among MNOs affects overall investment. Second, in terms of static efficiency, we examine possible gains when MVNOs actively participate in the market. We look at whether mobile prices decrease and whether the number of subscribers to mobile services increases.

For the purposes of the study, we estimated a system of simultaneous equations for investment, adoption, and price. Our unbalanced panel data set includes information on market performance and investment of 58 incumbent mobile network operators, the presence of MVNOs, access regulation, and other market-specific factors in 21 Organisation for Economic Co-operation and Development (OECD) countries for 35 quarters spanning from the first quarter of 2000 to the third quarter of 2008.

Our empirical results suggest that the presence of MVNOs decreases MNO investment. However, the estimates are statistically insignificant when we include the joint influence of MVNO presence and access regulation (which has a significant and negative effect on MNO investment). Our results also reveal that MNO investments decrease and mobile prices increase with MNO market concentration. Finally, MVNOs lower the prices of mobile

services of MNOs and increase the number of subscribers to MNO services. Overall, MVNO presence in the market enhances market efficiency but creates an incentive problem for MNO investment.

Few studies have dealt with MNO investment incentives in terms of MVNOs. For example, Foros et al. (2002) explored the relationship between roaming quality to MVNOs and investment incentives of a facilities-based firm, and in their game-theoretic approach, they show that quality improvement made by MVNOs reduces the investment of a facilities-based firm. This paper may be the first empirical study of the economic impact of MVNOs on MNO investment in the mobile telephony market across countries. We identify a trade-off between static efficiency (facilitating competition in services) and dynamic efficiency (providing incentives to invest in mobile network infrastructure).

The rest of the paper is organized as follows. Section 2 provides the theoretical background and hypotheses. Section 3 describes the data. Section 4 presents the empirical model. Section 5 reports and discusses the estimation results. Finally, section 5 summarizes the findings and draws some policy implications.

2. Theoretical background

Hausman (1997) as well as Röller and Waverman (2001) show that investment in the telecommunications industry is essential for social welfare and long-run economic growth. However, regulation in the telecommunications market may impose welfare costs by delaying deployment of innovative technologies or reducing the amount of investment (Hausman, 1997; Alesina et al., 2005).

In general, conventional wisdom suggests a trade-off between the static efficiency associated with current competition and the dynamic efficiency related to current investment. Dynamic, or long-term, efficiency may grow at the expense of short-term efficiency. The promotion of dynamic efficiency that encompasses risky innovations and investments may violate some of the conditions that are important for static efficiency. For example, entry barriers that limit competition and market dominance that allows firms to charge prices over cost may facilitate dynamic efficiency (Bauer and Bohlin, 2008).

2.1. Access regulation

The experience of local loop unbundling earlier in the United States shows the trade-off between the regulatory effects on the short-run market and long-run facilities-based investment (Hausman, 1997; Bauer and Bohlin, 2008). Regulatory policies on unbundling focused on the static side of efficiency by allowing service-based entry, but policy makers paid less attention to investment incentives (Jorde et al., 2000; Hausman and Sidak, 2005). Jorde et al. (2000) argued that the unbundling of network elements diminishes incentives for both service-based entrants and facilities-based operators to invest in existing facilities and new technologies. Waverman et al. (2007) also argued that regulation on unbundling has a negative effect on investment. Although a few disagree on the impacts of unbundling regulation, most studies conclude that unbundling reduces investment incentives in advanced Internet infrastructure (e.g., Wallsten, 2006).

The same concerns for local loop unbundling of fixed-line Internet have emerged for MVNOs. When there is access granted to MVNOs in the mobile telephony market, there is a tradeoff between facilitating competition in services and prices and providing incentives to invest into mobile network facilities (Dewenter and Haucap, 2007). Foros et al. (2002) show that investment levels decrease when the quality of access provided to MVNOs increases.

From the literature on unbundling in the fixed-line Internet market, we discuss the theory behind investment incentives of MNOs that provide access to MVNOs. We begin with the two economic characteristics of access regulation: investment spillovers and an asymmetric allocation of risk and returns on irreversible investments.

2.1.1. Investment spillovers

An MVNO with access to the mobile network infrastructure can constrain the ability of an investing firm to appropriate the benefits from investments. This is manifested by investment spillovers.

The provision of access to an MVNO can induce spillovers that arise from MNO investment in replacing old facilities, adopting new mobile technologies, or improving the current network infrastructure. When an MVNO is able to access an MNO's network and serve its own customers, improvements in quality or benefits from new technologies used in the network make MVNO service offerings more attractive to the market. In this manner, the MVNO can share some of the positive outcomes from MNO network investment. Consequently, the MNO may face lower returns from its investments. Foros (2004), Woroch (2004), and Kotakorpi (2006), among others, forwarded this argument.

Griliches (1992) emphasized that investment spillovers are different from knowledge spillovers. In fact, under certain conditions in the mobile access market, MNOs are willing to give access to their networks voluntarily. Some moderating factors may mitigate incentive problems stemming from spillovers. For example, a part of the spillover may be recovered if the MVNOs can afford a higher access fee charged by the MNO. Foros (2004) showed that without access-price regulation and with a competitive downstream sector, a vertically integrated firm has an incentive to invest because its downstream rival is more efficient in offering services. Similarly, Kotakorpi (2006) showed that without access-price regulation, investment spillovers may positively affect investment because an incumbent makes profit in the access market.

However, these predictions are reversed in some situations. For example, if a service-based entrant is less efficient at offering services, then the MNO may lower the level of investment or denies access (Kotakorpi, 2006). Insufficient differentiation of MVNO services causes loss of the MNO profit as the competition effect outweighs revenue from the access market, and therefore, MNOs will not allow MVNO access (Dewenter and Haucap, 2007). That is, despite any voluntary agreement of MNOs to allow access to MVNOs, the market mechanism may not support the access market or may result in MNO underinvestment.

When MNOs refuse to make an access-provision agreement with MVNOs, regulatory intervention can force them to provide market entry to MVNOs. Regulatory authorities mandate access provision with or without access-price regulation or regulate access pricing

such that it facilitates MVNO entry. Unfavorable conditions forced upon MNOs may cause adverse effects on their investments. Mandatory access provision of upgraded or advanced facilities to services-based downstream rivals may result in more fierce competition in the retail market. Moreover, spillovers that benefit rivals shift some of the incumbent's profit to the service-based competitor. Accordingly, MNOs expect their profits to be lower due to more intense downstream competition. This may reduce investment and deployment of the network (Woroch, 2004). When access price is regulated to be at or close to marginal costs and a vertically integrated firm cannot expect to earn profits from its investment, it has a lower incentive to invest (Foros, 2004; Waverman et al., 2007). Kotakorpi (2006) showed that when it is forced to provide access at a low price, the incumbent cannot secure a profit from access provision; in contrast, MVNOs enjoy benefits from any MNO investment. Spillovers discourage investment and the level of investment is lower than in the absence of regulation. Therefore, access regulation will exacerbate an investment disincentive for MNOs.

2.1.2. Asymmetric allocation of risk and the return on irreversible investments

The second characteristic of access regulation, which is due to the irreversible nature of the investment, is the asymmetric allocation of risks and uncertainty of consequent returns (Pindyck, 2004). The extent to which this argument is relevant to the case of mobile communications depends on the extent to which investments in mobile technologies are irreversible.

The level to which the capital is physically recoverable and is industry-specific affects the irreversibility of any capital expenditure (Pindyck, 2004). For example, investment in fixed landline networks, such as those of copper or fiber-optic cables, require a large amount of cost recovery. For highly industry-specific capital, it may not be easy to find a buyer and sell that capital. In particular, this situation may apply to the mobile telecommunications industry where a number of the licensed owners of radio spectrum are subject to government regulation.

The risks of irreversible investments are exacerbated when combined with long lead times, long physical lifetimes, and large economies of scale (Guthrie, 2006). These factors encompass the fundamental reasons that investing firms have difficulty adapting their capital stocks to changes in the regulatory environment or to technological progress once the investments are undertaken.

Access regulation that allows MVNO investment flexibility exposes MNOs to considerable risk. If its investment in facilities is largely irreversible, the MNO must bear heavy sunk costs and risks originating from market conditions. However, unlike MNOs, MVNOs that simply lease an MNO's network do not need to take risks of irreversible investment.

Risks regarding uncertain market conditions over the lifetime of physical capital change the expected return of capital spending. Moreover, downstream competitors and regulated access to MVNOs may distort the distribution of risk between MNOs and MVNOs. If market conditions are unfavorable, an MVNO will not enter and will wait to lease an MNO's network. However, an MNO must face the economic cycle with its irreversible

facilities. The MVNO will go for access in good market conditions. The MVNO has investment flexibility; it shares the upside risk with MNOs by acquiring access but avoids the downside risk by abandoning access or not leasing network facilities (Guthrie, 2006). Therefore, access regulation allocates more risk to MNOs and less to MVNOs, leading MNOs to expect relatively low returns on investment in the absence of access regulation (Jorde, 2000; Pindyck, 2004; Guthrie, 2006).

Moreover, access regulation leaves MNOs incurring the whole cost of unsuccessful investment and the entire risks on consumer adoption, whereas their downstream rivals can wait until an investment turns out to be successful (Jorde et al., 2000). This also reduces the expected return to investment for MNOs. Therefore, because of the nature of irreversible investment, access regulation creates an investment disincentive for MNOs by creating an asymmetric allocation of risks and payoffs.

We constrain the focus of this paper to the investment problem of network-operating incumbents under access regulation. We address the overall effect of MVNOs and access regulation regardless of market conditions, specific regulation, MVNO capabilities, or MNO strategies that may compensate for loss due to spillovers. Therefore, we expect that when MNOs are mandated to allow MVNO access to their networks their incentives to invest will decrease.

2.2. Competition among mobile network operators and their investment incentives

In addition to the impact of access regulation, we examine whether market competition discourages MNO investment and explore the effect of competition between incumbents (MNOs) on investment intensity.

Arrow (1962) favored competition to foster innovations while Gilbert and Newbery (1982) suggested that a monopolist with the threat of entry from prospective competitors has more incentives to innovate preemptively. Tirole (1997) called these two forces "the replacement effect" and "the efficiency effect," respectively.

Arrow showed that a monopolist has fewer incentives to invest in process innovations than a competitive firm does, because the monopolist with a new technology must replace the customer base related to its old technology. That is, the greater profit a firm can earn from an old technology, the greater the replacement effect it faces in implementing a new technology. This conclusion implies that market competition provides a favorable environment for investment in innovations.

However, according to Gilbert and Newbery (1982), the monopolist makes preemptive innovations or adopts new technologies to deter potential rivals' entry. With the efficiency effect, an incumbent in a less competitive market may have more investment incentives than it would experience in a more competitive market.

In the mobile telephony market, the government regulates entry by granting the use of scarce radio frequencies to the firms capable of investment and providing services. Whether a facility-based entrant is allowed into the mobile telephony market depends on the extent to which the intensity of current market competition encourages market efficiency. Entry also depends on investment incentives and the length of time for the risky and heavy

investment in infrastructure to be recouped. This means that market entry does not remain solely a potential entrant's decision. Therefore, the efficiency effect may be weaker than the replacement effect, particularly in the mobile telecommunications market in light of entry regulation.

Following Arrow (1962), MNOs likely have fewer incentives to invest in a network where competition is less intense due to cost-reducing investment that corresponds closely to investment in process innovations. Gilbert (2006) extended the definition of the replacement effect to include investment in product innovations. These innovations are associated with investment in adopting advanced technologies to operate mobile technology. According to Gilbert, perfect replacement of an old product with a new product leads to the same consequence outlined by Arrow (1962), because a monopolist would need to replace profit from old technologies with profit from new technologies. However, this replacement effect is attenuated if a monopolist can add a new product to its portfolio rather than simply replace an old one.

It follows from this discussion that competition is more likely to provide greater incentives for investment in networks under the two conditions suggested by Gilbert (2006). First, competition in the present mobile market lowers the pre-investment profit, and hence, reduces the replacement effect for a competitor. This results in an increased incentive to invest. That is, under intense competition, the replacement effect is smaller than in weak competition. Second, the advanced mobile services rendering the old mobile services obsolete reinforce the replacement effect. For example, even though the speed of replacement matters, the 3G mobile technology and service will ultimately replace the 2G service. As 3G replaces 2G, MNOs in less intensely competitive markets face a stronger replacement effect and have lower incentive to invest.

For the mobile telecommunications market, the more concentrated the market structure, the more likely MNO incentives to invest will drop as a whole.

3. Econometric approach

3.1. Data

The data are mainly drawn from the Wireless Intelligence database (see https://www.wirelessintelligence.com), which provides the financial and operational performance of network operators in mobile markets. We selected 58 MNOs operating in 21 countries for 35 quarters from 2/2000 to 3/2008. Unfortunately, not all MNOs have a full set of data for the full period of study. Each MNO reports capital expenditures (CAPEX), average revenue per unit (ARPU), and revenue in U.S. dollars (USD), market share, and the number of connections by type of mobile technology standards. CAPEX represents expenditures on adding, maintaining, or upgrading physical assets such as equipment, property, and plants. ARPU is the total revenue divided by the weighted average number of customers. The number of connections is a proxy for the number of subscribers. Market share measures the fraction of the market that a firm has in terms of the number of connections.

World Cellular Information Services (WCIS, see http://www.wcisplus.com) provides data on mobile technologies, access networks, and subscriptions of MVNOs. These data identify 80 MVNOs in 16 out of 21 countries from 1/2000 to 2/2009. The number of MVNOs reported in the WCIS database is relatively small. Because of the diverse definitions and scope of MVNOs across countries, this figure implies that the data apply a narrow definition of MVNOs.

We collected information on the regulatory environment in each country from several sources.[2] Because the nature of access provision differs across countries and varies across time, comparable time-series data on regulation for each country are difficult to compile. For this reason, we use changes in the regulatory policies only relevant to mandatory provision of access.

3.2. Dependent variables

We focus on the impact of MVNOs on investment and market efficiency by examining MNO investment, adoption, and prices. The dependent variable for investment is investment intensity; to eliminate firm-size effects, we measured INVEST as the natural logarithm of the ratio of CAPEX to revenue. SUB, for the adoption, is the natural logarithm of the number of connections. PRICE, is the natural logarithm of ARPU.

3.3. Mobile virtual network operators and the regulation variables

The dummy variable MVNO measures the presence of an MVNO (regardless of the number of MVNOs). Different data sources report the number of MVNOs as ranging from 80 to 400 in any given year. This reflects the diverse definitions and scope of MVNOs across countries. The data used for this study have a relatively small number of MVNOs in each year compared to the numbers reported in other data sources, which may reflect a narrower definition of MVNOs applied to the classification of mobile operators.

The regulation variable is a dummy intended to capture the effect of access regulation. The regulation of MVNO access and the trajectories of reform are very complex and difficult to identify because market environments and MVNO business models differ in time and across countries. In addition, access provisions are regulated in many ways such that, once again, comparable data across countries are difficult to compile.

We view mandatory access regulation as strong regulation. The other category includes no policy, any type of voluntary provisions, threats of regulatory intervention, and others that we cannot identify.[3] In many countries with MVNOs active in the mobile telecommunications markets, access regulation has been replaced with voluntary negotiation-based provisions[4] or access regulation did not exist over our sample period.[5]

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[2] These sources are listed separately in the reference section.

[3] In some countries (e.g., France, the United Kingdom, etc.), the regulatory authorities have announced that they monitor joint dominant market position or market competition of incumbent MNOs over time to decide on access regulation. These actions may restrict MNO investment, possibly leading to higher market shares, or they will intervene in the case of failure to reach a voluntary agreement between MNOs and MVNOs.

[4] For example, Australia, Denmark, the United States, and Sweden, among others.

Thus, we suppose that voluntary provision constitutes the majority of the observations in our sample. As shown in Table 1, to evaluate the regulation effect compared to the absence of MVNOs (i.e., MVNO=0), REG has the value of 2 under mandatory access provision and 1 otherwise. Then, we created an interaction variable of MVNO and a regulation variable of MVNO*REG. The coefficient on MVNO estimates the effect of MVNOs, while the coefficient on the interaction variable measures the additional effect of mandatory access regulation (REG=2) as compared to the average effect of other cases, such as voluntary provisions, threats of regulatory intervention, and so forth (i.e., REG=1).

<Table 1> here

Table 1 shows that in some periods some countries have no active MVNOs. In these countries, MNOs are treated as if they did not face access regulation. Obviously, when MVNO=0, it does not make any difference to the estimation if REG takes a value of 1 or 2. Therefore, in countries and time with no MVNOs in the markets, the effect of policies on access is ignored.

3.4. Market concentration

Apart from competition induced by MVNOs in the market, competition among MNOs is also an important force affecting the level of any MNO's investment. If market competition is not sufficient to encourage the investment of MNOs, access regulation or any regulatory interventions may be justified.

The Herfindahl-Hirschman Index (HHI) is a traditional measure of market structure. Our data on the market shares of MNOs do not include the market shares of any MVNOs. This characteristic of the data allows us to examine MNO investment independently of the influence of MVNOs.

3.5. Other controls

Mobile services that use advanced technologies (e.g., 2G, 3G) or different technological standards (e.g., GSM, CDMA) require a considerable amount of prior and subsequent investment. When this is the situation during MVNO entry, sudden increases of capital expenditure is likely to lead to biased results. More important, such changes may influence the presence of MVNOs and regulation, leading to an endogeneity problem. We introduce three TECH variables with lags of -1, 0, and +1 to control for these potential effects.[6]

Firm characteristics affect the decisions of investment and consumer subscriptions as well as the pressure for giving access to MVNOs. SIZE is the natural logarithm of firm revenue and capture advantages arising from firm size. AGE is the natural logarithm of firm age and is included to reflect firm characteristics.

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[5] For example, France, Germany, the United Kingdom, etc.

[6] However, some MNOs in Canada and the United States have been involved in a number of mergers and acquisitions (M&A) to increase their market shares with existing mobile technologies or to start new services using different mobile communications standards. Although the numbers of M&A occurrences are few, we excluded cases of M&A from TECH.

Other control variables include dummies for quarters and years as well as national income. INCOME is measured as the natural logarithm of gross domestic product (GDP) per capita (in U.S. dollars and purchasing power parity). All the nominal variables are converted to constant 2000 US dollars. A summary of the variable descriptions is contained in Table 2 and the correlation coefficients are reported in Table 3.

<Tables 2 and 3> here

3.6. The model

We estimate a system of three equations for investment, adoption, and price to assess the influence of MVNO and access regulation with the primary focus on a firm's investment behavior. As Figure 1 shows, all the equations have the MVNO, regulation, and competition-related variables (MVNO, MVNO*REG, and HHI) in common, but differ in the other variables, which control firm-specific and country-specific factors as well as any time-related effects. The subscripts of the variables denote firm (*i*) and country (*j*).

<Figure 1> here

Investment equation:

$$INVEST_{ij} = \alpha_0 + \alpha_1 MVNO_j + \alpha_2 MVNO * REG_j + \alpha_3 HHI_j + other\ controls + \varepsilon_{ij}$$

Adoption equation:

$$SUB_{ij} = \beta_0 + \beta_1 MVNO_{jt} + \beta_2 MVNO * REG_j + \beta_3 HHI_j + \beta_4 PRICE_{ij} + other\ controls + \mu_{ij}$$

Price equation:

$$PRICE_{ij} = \gamma_0 + \gamma_1 MVNO_j + \gamma_2 MVNO * REG_j + \gamma_3 HHI_j + other\ controls + \upsilon_{ij}$$

In the investment equation, we expect that mandatory access regulation has a negative influence on MNO investment intensity due to investment spillovers and the asymmetric allocation of risks and uncertainty of return. We also expect MNO competition (HHI) to be associated negatively with the intensity of investment. For the other controls, SIZE and AGE are proxies for firm characteristics, and TECH controls for any surge in investment to adopt new mobile technologies. The variables for quarter and year represent any systematic changes over time that affect MNO investment. ε_{ij} is an error component that captures unexplained factors in the variation of investment intensity.

In the adoption equation, we expect that mandatory access regulation has a positive influence on the number of subscribers to MNO services. To ease increasing non-price competitive pressure with MVNOs, MNOs will try to differentiate themselves from MVNOs by exerting more marketing effort or by introducing new bundles of services. HHI is expected to be negatively associated with adoption of MNO mobile services. The

equation includes SIZE and INCOME. The variables for quarter and year represent technological progress over time that affects adoption trends. They represent continuous upgrades in service quality, greater range of services available, and cheaper mobile handsets. μ_{ij} is an error term.

In the price equation, we expect that mandatory access regulation encourages price competition by easing MVNO entry into the mobile telephony market. MVNOs can lease MNO networks so that they may have cost advantages over MNOs. Also, they may be more eager to establish market share. As economic theory indicates, weak MNO competition is related to higher mobile prices. INCOME is a proxy for customer willingness to pay and for any country-fixed effects. The time variables for quarters and years are included in each equation, and υ_{ij} is an error term that represents unexplained parts of changes in mobile prices.

4. Estimation findings

Our data is an unbalanced panel with a number of missing observations; hence, all of the observations in time are pooled, so we have 1343 observations for 21 countries. In our setting, PRICE is both a dependent and an explanatory variable in the adoption equation. A system of these kinds of equations suffers from an endogeneity problem that occurs when each equation is regressed in isolation, i.e. the residuals of the relevant equations are likely to be correlated. Accordingly, we estimate the three equations simultaneously using three stage least squares (3SLS); doing so allows for the correlation of the residual terms of the three equations.

The exogenous instrumental variables for PRICE comprise all the explanatory variables in the three equations, regional dummies (Eastern Europe, Western Europe, North America, and Asia), the lagged values of MVNO, HHI, and the three dependent variables.

Table 4 shows the regression results. The columns labeled Model 1, Model 2, and Model 3 report separate regressions. The different specifications in the investment equation show the effects of mandated MVNO access on MNO investment (Model 1 vs. Models 2 and 3). To assess the differential impact of MVNO and mandatory access regulation, the interaction term (MVNO*REG) is included in Models 2 and 3.

<Table 4> here

4.1. Mobile virtual network operator and the investment of mobile network operator

In the investment equation of Model 1, the estimated coefficient of MVNO is statistically significant at the 1% level and negatively related to the MNO investment intensity. The MVNO variable takes a binary value of either 0 or 1. Switching from 0 to 1 is associated with a decrease in investment intensity of 26.6%.

We assess the impact of MVNOs on the investment intensity for an average firm as follows. With the explanatory variables replaced by the average values in Table 2 (except MVNO), we simulate the percentage change of investment intensity with the predicted values when the value of MVNO varies from 0 to 1 as below.

Predicted change in investment intensity $= \left(\frac{\hat{I}_{MVNO=1} - \hat{I}_{MVNO=0}}{\hat{I}_{MVNO=0}} \right)$

In this calculation, $\hat{I}_{MVNO=1}$ is the predicted investment intensity at MVNO=1 and $\hat{I}_{MVNO=0}$ is the predicted intensity at MVNO=0.

The predicted reduction in investment intensity is approximately 15%. As a change in the intensity of investment means smaller investment with size fixed, this implies that MVNOs or access provisions reduce MNO investment incentives. This result does not suggest that such a reduction in the investment intensity may arise from activities of a single MVNO in the market. Rather, it reflects the average effect of MVNOs in reducing MNO incentives to invest, illustrating the diverse and complex regulatory and business surroundings such as the number of MVNOs, business models of MVNOs, strategies of MNOs providing access with MVNOs, and so on. Moreover, Model 1 does not take the type of regulation into account. Therefore, we needed to separate the provision of mandatory access, which is of our primary interest.

We consider the impact of access that may affect the size of the economic effects of MVNOs. In the investment equations of Model 2 and 3, we seek to capture the effect that a mandate to provide access may exercise on MNO investment.

The interaction variable MVNO*REG has a negative sign and is statistically significant at 5% while the estimated coefficient of the MVNO variable remains negative but becomes insignificant.

We further assess the size of the negative impact on investment for an average MNO as follows.

Predicted change in investment intensity $= \left(\frac{\hat{I}_{MVNO\_REG=i} - \hat{I}_{MVNO\_REG=0}}{\hat{I}_{MVNO\_REG=0}} \right), \ i = 1, 2.$

Here, $\hat{I}_{MVNO\_REG=0}$ is the predicted intensity of investment at MVNO*REG=0 (MVNO=0) and $\hat{I}_{MVNO\_REG=i}$ at MVNO*REG=1 or 2.

The calculation using the average values of the explanatory variables predict reductions of 7.4% (Model 2) and 7.6% (Model 3) in investment intensity when MVNO*REG=1. When the value of MVNO*REG changes from 1 to 2, the intensity of investment exhibits a decrease of 6.9% (Model 2) and 7.1% (Model 3). Finally, the prediction (MVNO*REG=0 to 2) imply reductions of 14.8% (Model 2) and 15.3% (Model 3), which are close to the size of the estimated reduction in Model 1.

The negative effects of mandatory access regulation (MVNO*REG=2) on investment are greater than those of the average effects of the other cases, such as (mostly) voluntary access provisions and threats of regulatory intervention (MVNO*REG=1). Because REG=1 covers voluntary agreements on access to MNO networks, threats of regulation by authorities, and so forth some of the other kinds of access provision are also related to lower investment intensity. Of note, our results imply that market-based provisions are also highly likely to generate a disincentive for MNO investment because of a relatively large

portion of voluntary provisions in REG=1 in our sample; however, the effect of voluntary agreements on access provisions between MNOs and MVNOs is mixed with the effect from less stringent regulation.

Our results suggest that mandatory access regulation undermines MNO investment incentives while, to a lesser extent, voluntary agreements may also reduce investment in the mobile network.

In general, MNOs have lower incentives for investment when they experience insufficient appropriation on their past investments or when they expect to lose some future rents from current investments in the network infrastructure by allowing MVNO access to their network.

4.2. Competition among mobile network operators

In the investment equation of Model 1, the square of HHI shows a significant inverted U-shaped relationship between investment intensity and competition among MNOs. The total effect of MNO market structure on the investment intensity is negative over the range of the HHI values in the sample. In Models 2 and 3, the coefficients of HHI are negative and significant at the 1% level. A highly concentrated MNO market structure is associated with a lower incentive to invest. From the perspective of the replacement effect, as an incumbent MNO takes a greater share in the mobile telecommunications market, it becomes less likely to invest due to the smaller incremental profit that it will earn and the greater existing customer base that it will need to replace.

As for adoption, Models 1, 2, and 3 indicate that the coefficients of HHI are insignificant. However, the coefficients of HHI are positively related with mobile prices at significance levels of 5% and 1%. This implies that to lower mobile prices, entrants to the market should be encouraged so that competition increases and incumbents' market shares decrease. MVNOs are an effective tool to ease or detour intrinsic entry barriers caused by the limited radio spectrum.

Although dynamic and market efficiencies are often considered to offset one another, the mobile telecommunications markets in our sample tend to display less investment and higher prices as MNO market concentration increases. This finding demonstrates that both efficiencies are moving together in an undesirable direction.

However, this result does not necessarily imply a need for regulatory intervention that would lessen investment disincentives and enhance market efficiency by increasing competition. One cannot simply judge that the level of current investment is insufficient or service diversity and prices are not satisfactory. Successful regulatory intervention would partly depend on the extent to which the current deployment of mobile network or mobile technologies coincides with and supports the development of other relevant technologies and market needs, such as mobile internet, Digital Multimedia Broadcasting, mobile video telephony, and so forth.

4.3. Static and dynamic efficiencies of mobile virtual network operators and access regulation

From the perspective of dynamic efficiency, we find that access regulation discourages the investment of MNOs, and voluntary access provision is also likely to reduce MNOs' incentives to invest. Now, we examine whether or not MVNOs and access regulation improve market efficiency.

In the adoption equation of all estimation models, the estimates of the variable MVNO reveal a significant positive effect on the number of MNO subscribers. Because we controlled for any effect of price changes arising out of price competition in the adoption equation, this finding implies that MNOs undertake non-price competition against MVNOs to increase market share. MVNO*REG is not significant in the adoption equation of Model 3.

In the price equation, the effects of MVNOs are significant and have a negative influence on mobile prices in Models 1 and 2. This finding indicates that MNOs become involved in more intense price competition with MVNOs. However, in Model 3 the coefficient of the interaction term (MVNO*REG) of MVNO and regulation is significant and related to price reductions. Regulation of access is associated with price changes but not significantly relevant to a change in the number of subscribers.

MVNOs account for a positive change in the firm-level adoption in Models 1, 2, and 3 as well as a negative influence on mobile prices in Models 1 and 2. Mandatory access regulation has a differential joint effect on mobile prices but not on adoption in the estimation of Model 3. The results for adoption and prices may be attributable to more marketing efforts, the better and greater service offerings of MNOs, and intense price competition in response to MVNOs.

MVNOs are expected to accelerate service-based competition in the short-term and encourage investment in mobile telecommunications infrastructure in the long-term. We find that the presence of MVNOs can enhance market efficiency by stimulating MNOs to lower mobile prices and provide more differentiated services that they deliver to the market. However, MNOs competing against MVNOs have incentives for investment. When MNOs are forced to allow access to their networks, MVNOs create disincentives to invest.

5. Conclusions

MVNOs have been acquiring a growing reputation as an effective tool for promoting competition in the mobile telecommunications market across world. This market is characterized by facilities-based entry impeded by a burden of heavy investment and a limited radio spectrum. Advocates of MVNOs argue that although MVNOs can make great contributions to competition and innovation, they will not survive in the long-term without government intervention because MNOs seek to extract all profits from the mobile market. However, opponents of MVNOs insist that regulation will undermine investment incentives for MNOs.

In this paper, we presented a particular focus on MNO investment incentives in the mobile network market. We investigated the role of MVNOs and related regulation change while exploring the market-side consequences of both.

Granting MVNOs access to MNO networks will have profound consequences. From our results, access regulation and MVNOs not only encourage greater competition through MVNO activities in the market, but they also affect MNO investment incentives. Regulation in the mobile access markets has a negative effect on investment incentives while it improves market efficiency by lowering mobile prices. In particular, mandated provision of access to MVNOs will cause disincentives for investment. Even though access regulation undermines MNO investment incentives, as the opponents of MVNOs insist, it is still important to improve market efficiency by encouraging market competition, as the proponents of MVNOs argue.

Threats of regulation on access, voluntary provision of access, and other factors that we did not figure in this study also affect MNO investment, adoption, and prices. Voluntary access provision is likely to lower MNO investment incentives. In addition to mandatory access provision, voluntary relationships between MNOs and MVNOs regarding access may be the source of the concern about long-term benefits for welfare even though these can bring beneficial short-term results to the market.

When disincentives are expected to affect the market adversely, regulatory intervention may be needed to correct them. If lower prices and better, more diverse services are the objectives of policy intervention, allowing MVNO entry is an effective way to achieve these objectives. Although mandatory provision of access may improve market efficiency via more intense competition, the accumulated underinvestment of MNOs may lead to undesirable results in the long-term, such as delayed deployment of advanced networks, poor service quality, and slow technological advances. If regulation encourages competition in investment by entry of facilities-based firms, then forcing access for MVNOs will undermine MNO investment incentives until facilities-based competition is realized. Moreover, if the ladder of investment argument does not hold in practice, the costs and the likelihood of undesirable outcomes are relatively great.

Therefore, we propose that regulation be designed to encourage investment incentives of MNOs as well as raise customer satisfaction with more diverse services offered at lower prices. In other words, policy makers should be more concerned with the impact of MVNO access on the investment side, so regulations can simultaneously improve both market and dynamic efficiencies, which is more desirable.

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Figure 1
Empirical framework

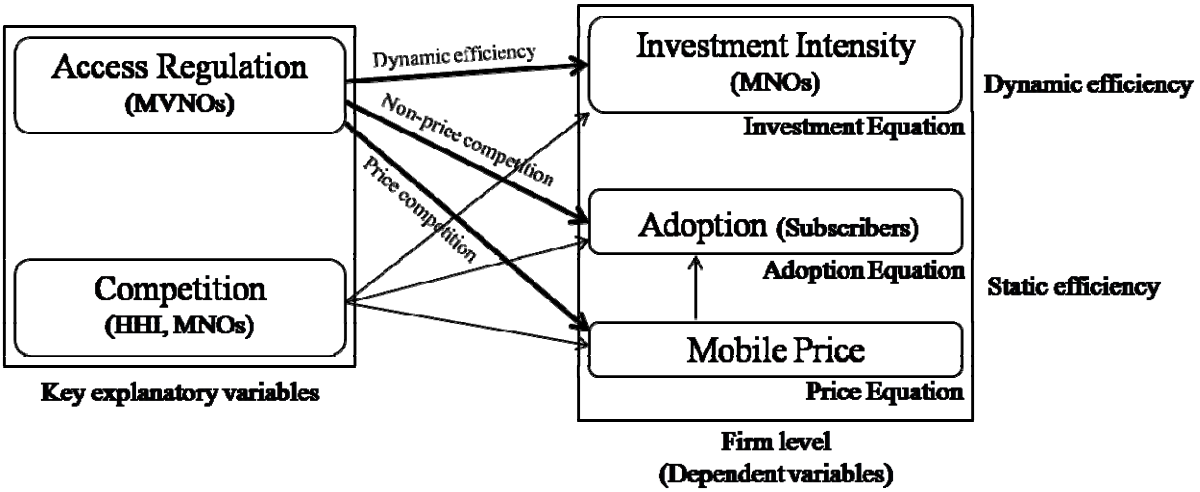

Table 1
Mobile virtual network operators and regulation

Country	Period of MVNO=1 in the sample (quarter/year)	REG=2	REG=1
Australia	4/2000-3/2008	○(~1/2001)	○(1/2001~)
Austria	-	-	-
Belgium	3/2006-3/2008	-	○
Canada	4/2005-3/2008	-	○
Czech Republic	-	-	-
Denmark	4/2002-3/2008	○(~1/2006)	○(2/2006~)
Finland	1/2002-3/2008	-	○
France	3/2004-3/2008	-	○
Germany	4/2001-3/2008	-	○
Greece	-	-	-
Italy	2/2007~3/2008	-	○
Japan	-	-	-
Korea	-	-	-
Norway	1/2000-3/2008	○(1/2006~)	○(~4/2005)
Poland	4/2006-3/2008	-	○
Portugal	3/2005-3/2008	-	○
Slovakia	-	-	-
Spain	4/2006-3/2008	○(1/2006~)	○(4/2000~4/2005)
Sweden	1/2003-3/2008	○(2/2000~3/2005)	○(~1/2000)(4/2005~)
United Kingdom	4/2002-3/2008	–	○
United States	2/2002-3/2008	○(~4/2002)	○(1/2003-)

Note:
1) REG=1 includes other ways of providing access, such as voluntary provisions, threats of regulatory intervention. REG=2 denotes mandatory access provisions.
2) For countries where no MVNOs are active, then MVNO*REG=0. This implies that the effects of any regulations are ignored in our analysis.

Table 2
Descriptive statistics

Variables	Description	Mean	Std. dev	Min	Max
Dependent variables					
INVEST	The intensity of investment, (ln) capital expenditure/revenue for each MNO	-1.9084	0.71684	-4.23	1.39
SUB	(ln) number of connections for each MNO	15.5912	1.1268	12.8	18.08
PRICE	Mobile prices, (ln) ARPU for each MNO	3.6598	0.2752	2.83	4.36
Regulatory and competition variables					
MVNO	Dummy variable = 1 if a MVNO exists, 0 otherwise	0.5093	0.5000	0	1
MVNO*REG	Dummy variable = 0 if a MVNO does not exist, 1 if a MVNO exists and REG = 1 (voluntary provisions, threats of regulatory intervention, etc.), 2 if a MVNO exists and REG = 2, mandatory provision of access	0.5837	0.6262	0	2
HHI	Herfindahl-Hirschman Index, sum of squares of market share	0.3055	0.0964	0.13	0.51
Other variables					
SIZE	(ln) revenue in USD of a MNO	20.4417	1.1960	17.21	23.25
AGE	(ln) firm age in year	2.6083	0.8944	0	5.03
TECH(-1)	Dummy variable = 1 if one quarter prior to the launch of services using different mobile technology, 0 otherwise	0.0632	0.2435	0	1
TECH(0)	Dummy variable = 1 if providing services using different mobile technology, 0 otherwise	0.0640	0.2449	0	1
TECH(+1)	Dummy variable = 1 if a quarter after launching mobile services using different mobile technology, 0 otherwise	0.0632	0.2435	0	1
INCOME	(ln) GDP per capita in USD and PPP	10.2226	0.2989	9.24	10.64

Note: All the nominal variables are deflated at 2000 USD.

Table 3
Correlation coefficients

	INVEST	SUB	PRICE	MVNO	HHI	REVENUE	TECH(-1)	TECH(0)	TECH(+1)	AGE	INCOME
INVEST	1										
SUB	-0.0826*	1									
PRICE	-0.0071	0.1020*	1								
MVNO	-0.2284*	0.1080*	0.0385	1							
HHI	-0.1371*	-0.0964*	-0.1689*	-0.3233*	1						
REVENUE	-0.0805*	0.9361*	0.3603*	0.1048*	-0.1259*	1					
TECH(-1)	-0.0341	0.0475*	-0.0240	0.0275	-0.0096	0.0390	1				
TECH(0)	0.0217	0.0548*	-0.0143	0.0515*	-0.0109	0.0450*	-0.0570*	1			
TECH(+1)	-0.0045	0.0610*	-0.0194	0.0669*	-0.0128	0.0462*	-0.0374*	-0.0570*	1		
AGE	-0.2526*	0.1773*	0.1426*	0.2950*	-0.2049*	0.2123*	0.0417*	0.0398*	0.0491*	1	
INCOME	-0.0594*	0.0675*	0.5116*	0.4641*	-0.4591*	0.1758*	0.0028	0.0067	0.0122	0.2409*	1

Note: * 10% significance

Table 4
Estimation results

	Estimation Models		
	Model 1	Model 2	Model 3
Investment Equation			
MVNO	-0.2655***	-0.0891	-0.0843
	(0.0418)	(0.0955)	(0.0956)
MVNO*REG		-0.1325**	-0.1364*
		(0.0717)	(0.0718)
HHI	-8.8977***	-1.3622***	-1.3616***
	(1.0266)	(0.2044)	(0.2044)
HHI^2	13.1192***		
	(1.7548)		
SIZE	0.0278*	0.0112	0.0110
	(0.0150)	(0.0154)	(0.0154)
AGE	-0.2003***	-0.1675***	-0.1674***
	(0.0294)	(0.0208)	(0.0208)
constant	-0.4805	-1.0694	-1.0661
	(0.3339)	(0.3248)	(0.3248)
Adoption Equation			
MVNO	0.0219***	0.0219***	0.0437***
	(0.0078)	(0.0078)	(0.0170)
MVNO*REG			-0.0183
			(0.0127)
HHI	-0.0531	-0.0536	-0.0490
	(0.0410)	(0.0411)	(0.0411)
PRICE	-1.0029***	-1.0030***	-1.0026***
	(0.0169)	(0.0169)	(0.0169)
SIZE	1.0078***	1.0079***	1.0073***
	(0.0029)	(0.0029)	(0.0030)
INCOME	-0.0613***	-0.0617***	-0.0608***
	(0.0169)	(0.0169)	(0.0169)
constant	-0.6760***	-0.6725***	-0.6709***
	(0.1610)	(0.1611)	(0.1610)
Price Equation			
MVNO	-0.0516***	-0.0517***	-0.0013
	(0.0143)	(0.0143)	(0.0308)
MVNO*REG			-0.0423*
			(0.0229)
HHI	0.1811**	0.1820**	0.1942***
	(0.0745)	(0.0745)	(0.0747)
INCOME	0.6265***	0.6272***	0.6288***
	(0.0250)	(0.0251)	(0.0250)
constant	-2.5923***	-2.5995***	-2.6164***
	(0.2649)	(0.2651)	(0.2649)
R^2 (Investment)	0.2149	0.1889	0.1889
R^2 (Adoption)	0.9897	0.9897	0.9897
R^2 (Price)	0.4437	0.4237	0.4251
Observations	1343	1343	1343

Note: * Significance p=0.1, ** Significance p=0.05, *** Significance p=0.01. Standard errors in parentheses. Time variables and TECH dummies are not reported.