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First Mover Advantages in Mobile Telecommunications: Evidence from OECD Countries

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Abstract

We explore the existence of first mover advantages in mobile telecommunications markets. Building on a data set comprising monthly penetration rates, market concentration, number of active operators, and market shares of 90 followers from 33 OECD countries, we estimate a dynamic growth model. Our analysis delivers five key results. Regarding a follower's long-run market share, we observe that (1) the penetration rate at the time of market entry exerts an inverted u-shaped effect, suggesting the existence of an optimal time for issuing additional licenses for mobile network operation; (2) the concentration rate at market entry exerts a positive effect, implying that it is easier for followers to enter a more concentrated market; (3) both the number of active operators at market entry and the number of currently active operators have a negative impact. Furthermore, we find that a follower's rate of convergence to the long-run market share is (4) negatively influenced by the current market concentration and number of active operators; (5) negatively affected by changes in the penetration rate since market entry, which strongly indicates the presence of substantial first mover advantages for pioneering network operators.

Keywords: First mover advantages; Asymmetric regulation; Market share convergence; Mobile telecommunications

JEL codes: L96, K23, O33

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I. Introduction

Do market pioneers, i.e. firms that enter a market first, have a first mover advantage (FMA) vis-à-vis followers, i.e. later entering competitors? Numerous studies in economics and both management and marketing research have investigated whether pioneering firms enjoy FMAs over followers (see e.g. Ethiray and Zhu, 2008; Carson et al., 2007; Frynas et al., 2006). The majority of these studies find empirical support for the existence of FMAs, which enable pioneering firms to set prices above competitive levels and thus gain excessive profits (Haucap and Dewenter, 2006). The topic of FMAs is especially important because recent studies on market share dynamics provide strong evidence that market leadership often persists for a long time, much longer than standard economic theory predicts (see, e.g., Sutton, 2007).

Since FMAs affect the cost position of firms, they are particularly important in regulated industries such as mobile telecommunications, where national regulation authorities (NRAs) regulate termination rates based on some (estimated) measure of operators' costs. If pioneering operators enjoy a superior cost position vis-à-vis later entering competitors due to FMAs, symmetric regulation of the termination rates of pioneers and followers allows the former to earn additional profits (Dewenter, 2007). This, in turn, further strengthens the competitive position of pioneers. Ultimately, this might impede the development of competition among mobile network operators, thereby thwarting the regulation authorities' objective of stimulating competition. Hence, the existence of FMAs in mobile telecommunication would support the policy of NRAs to implement an asymmetric regulation of pioneers and followers, to provide a level playing field for all market participants.

In recent years, several empirical studies have explored whether FMAs for market pioneers exist in the mobile telecommunications industry. The majority of these studies use linear models to investigate whether being the first to enter the market for mobile telecommunications exerts a positive influence on market shares, which would indicate the presence of FMAs. However, the linear representation of operators' market shares does not resemble the empirical observation that market shares in fact follow a nonlinear pattern: while market shares of pioneers follow a negative decreasing course, those of followers tend to follow a positive, but decreasing one. This holds true regardless of whether there are one, two, three, or four firms entering the market after the pioneer, as can be inferred from figure 1, which displays the course of market shares in four OECD countries, namely Iceland, Hungary, Germany, and Australia, for the period January 1990 to March 2008.

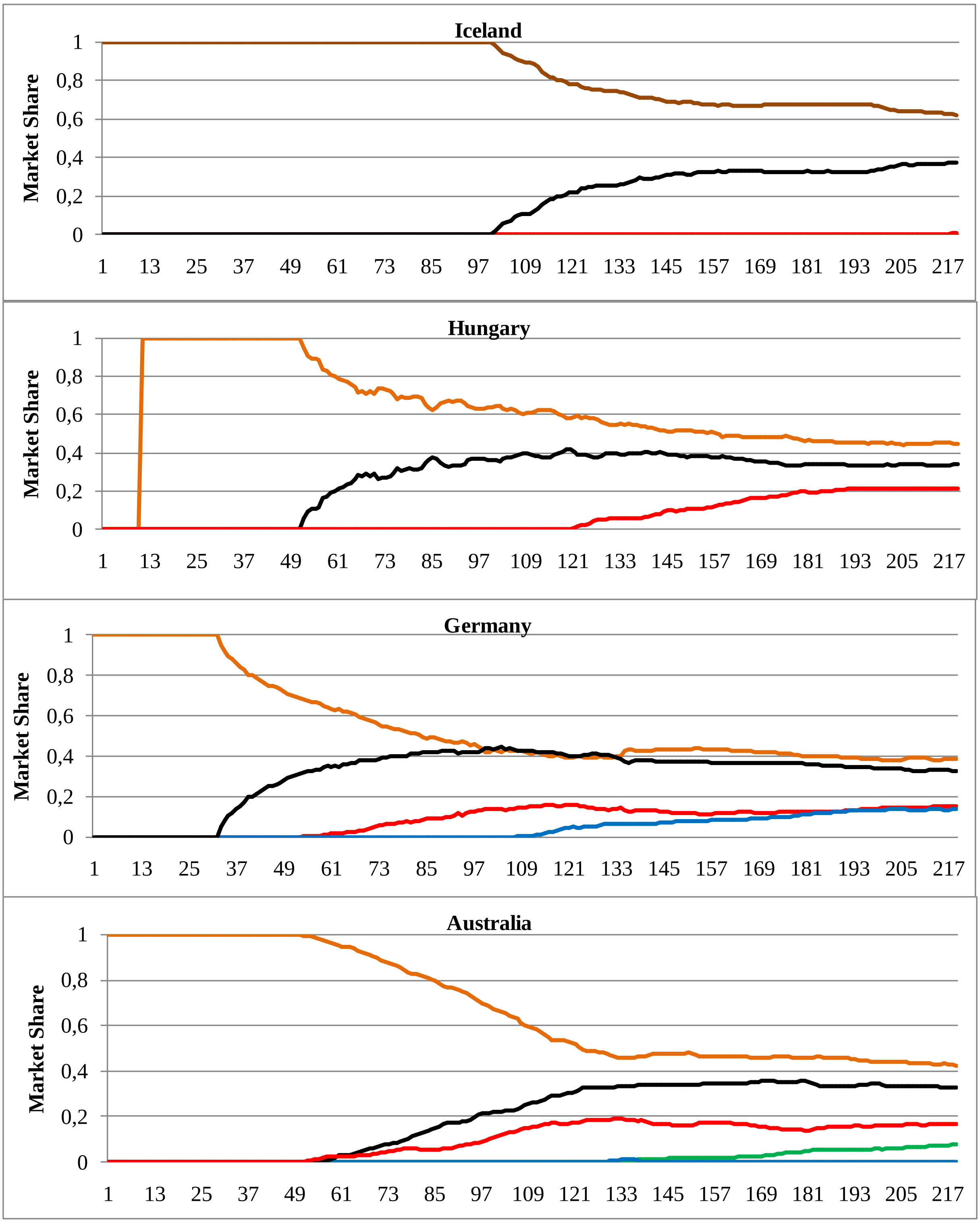

Figure 1: Market shares of mobile network operators in selected countries

Hence, it seems to be more appropriate to study FMAs in mobile telecommunications using a nonlinear econometric specification for the number of subscribers or market shares.

To the best of our knowledge, there exist only two empirical studies on FMAs in mobile telecommunications that explicitly account for the non-linear nature of operators' market shares. These are the studies of Haucap and Dewenter (2006), who studied 14 European countries for the period 1990 to 2005, and the study of Bijwaard et al. (2008), who used data on 16 European countries from 1990 to 2006.

In our study, we aim to further ground and extend the previous findings on FMAs in the mobile telecommunications industry by estimating an extended version of the nonlinear model used by Bijwaard et al. (2008) using data on 90 followers from 33 OECD countries covering the period from January 1990 to March 2008. Furthermore, by drawing on studies from the economics, management, and marketing literature, we are the first to provide a comprehensive overview of the empirical research on FMAs in mobile telecommunications.

The remainder of this article is structured as follows: in section two we review the existing literature on FMAs in mobile telecommunications. In section three we explore different sources of FMAs in mobile telecommunications and describe briefly why this market is particularly well suited for analyzing the existence of FMAs. In section four we specify our econometric model and derive testable hypotheses, before we state and interpret the results of our nonlinear least squares estimation in section five. We discuss possible limitations of our study and outline avenues for further research in section six.

II. Empirical research on FMAs in mobile telecommunications

Table 1 gives an overview over the existing empirical studies on FMAs in the mobile telecommunications industry. In addition to the authors' names and the publication year, the table also contains information on the type of model employed, the independent and dependent variables included, the time period, countries, and number of network operators covered by the study, and the core findings with respect to the existence of FMAs.

Table 1: Review of empirical studies on FMAs in mobile telecommunications

	Model			Data			
	Model-type	Explanatory variables	Dependent Variables	Period	Countries	No. of Firms	Core findings with respect to FMAs
zu Knyphausen-Aufseß, Krys, & Schneider 2002	case study	n.a.	n.a.	1994-2001	Greece, Germany	2	- The third entrant in the Greek mobile market, Cosmote, enjoyed a late mover advantage by successfully exploiting the inertia of its competitors - By introducing a radically simplified tariff scheme, offering postpaid rather than prepaid services, targeting of the mass market, and capitalizing on the resources of its parent, OTE, Cosmote became market leader within only three years
Kim & Kwon, 2003	multiple discrete-choice	- Age - Monthly payment - Monthly income - Network size - Price level	Mobile carrier selection	1999	Korea	5	- Consumers are more likely to choose larger networks - Older consumers are more likely to choose the pioneer
Gerpott, 2005	correlation analysis	- Time in market - Market share	- Market share - EBITDA	1992-2004	16	54	- Significant positive correlation between time in market and market share - Significant positive correlation between market share and EBITDA
Rieck, 2005	linear regression	- Time elapsed since entry of GSM / GPRS / MMS pioneer - Time since January 1990 - ARPU - Churn rate - Market share - Operational revenue - Number of employees - GDP per capita - Operator migrated from TDMA or CDMA	Tobin's q	2002	20	30	- Entering the GSM market early has a positive effect on performance - Entering the MMS market early has a negative effect on performance - ARPU and market share have a positive effect on performance
Sung, 2005	System of three linear regressions	- Market share - EBITDA - ARPM - Former state monopolist - Time in market - Number of operators - Frequency band used - Majority of shares held by a global operator - Penetration rate - Number portability - Number of subscribers - Population density	- Market share - EBITDA - ARPM	1998-2003	27 OECD countries	94	- Market share has positive impact on ARPM - ARPM has positive impact of EBITDA - EBITDA has positive impact on market share - Former state monopolists have higher market share - Time in market has positive impact on market share and EBITDA - Number of operators has negative impact on market share and ARPM - Operators owned by a globally active carrier have higher EBITDA - Mobile number portability has negative impact on ARPM - Number of subscribers has negative impact on ARPM - Penetration rate has positive impact on EBITDA - Population density has negative impact on ARPM

Table 1 (continued)

	Model			Data			
	Model-type	Explanatory variables	Dependent Variables	Period	Countries	No. of Firms	Core findings with respect to FMAs
Gerpott & Jakopin, 2006	linear regression	- Market entry through cooperation with already active network operator - Market entry through acquisition of shares of already active network operator - Market entry through foundation of new network operator - Degree to which entry is part of an internationalization strategy - Entry order - Time elapsed since entry of pioneer - 13 firm- and market-related control variables, among others: - Penetration rate - Number of active operators	Stock market reaction	1989-2004	16	29	- Entry through cooperation with/acquisition of shares of existing operators is inferior to entry through foundation of new operator - Entry order has negative effect on stock market reaction - Lead time of the pioneer has positive effect on stock market reaction - Penetration rate has no effect on stock market reaction - Number of active operators has no effect on stock market reaction
Haucap & Dewenter, 2006	non-linear regression	- Lagged number of subscribers	Growth in number of subscribers	1990-2005	14 European countries	n.a.	- The convergence of market shares of pioneers and followers is slower in countries that liberalized their market rather late
Atiyas & Dogan, 2007	case study	n.a.	n.a.	1994-2004	Turkey	4	- The long period of duopoly in the Turkish market created significant first- mover advantages for the two pioneering network operators - Regulatory mistakes further strengthened the position of the two pioneers
Fernández & Usero, 2007	log-linearized regression	- Entry order - Time in market - Market growth - Market concentration - Market has two pioneers - Number portability - Pre-entry experience	Erosion of pioneer's market share	1993-2005	EU, Norway, Switzerland	61	- Easier to gain market share from pioneer for early entrants - Easier to gain market share from pioneer if only one pioneer in the market - More difficult to gain market share from pioneer with pre-entry experience in markets with two pioneers - Easier to gain market share from pioneer if number portability is possible - Easier to gain market share from pioneer if market is growing - More difficult to gain market share from pioneer if market is concentrated
Bijwaard, Janssen, & Maasland, 2008	- non-linear regression - linear regressions	- Penetration rate at market entry - Market concentration at market entry - Market growth - Market concentration	Market share	1990-2006	16 European countries	45	Core results of the non-linear model: - A follower's long-run market share is negatively influenced by the penetration rate and market concentration at market entry - A follower's speed of convergence is influenced positively by market growth and negatively affected by the market concentration Core results of the linear models: - Market growth and market concentration have a positive impact on followers' market share

Table 1 (continued)

	Model			Data			
	Model-type	Explanatory variables	Dependent Variables	Period	Countries	No. of Firms	Core findings with respect to FMAs
Fernández & Usero, 2009	linear regression	- Heterogeneity in competitive conduct - Number of differentiation actions - Number of price actions - Market growth - Lead time of pioneer - Penetration rate - Market concentration - Pre-entry experience - Lagged market share	Gain in market share	1997-2000	EU, Norway, Switzerland	51	- Heterogeneity of competitive conduct positively affects gain in market share - Pioneers gain market share by using differentiation actions - Followers gain market share by using price actions - Market growth positively affects gain in market share - Penetration rate negatively affects gain in market share - Market concentration negatively affects gain in market share
Usero & Fernández, 2009	linear regression	- Relative product innovation activity - Relative marketing activity - Relative legal activity - Lead time of pioneer - Entry order - Penetration rate - Market growth - Lagged market share of pioneer	Erosion of pioneer's market share	1997-2000	EU, Norway, Switzerland (excluding Sweden and Luxem-bourg)	49	- If followers issue more legal actions relative to the pioneer they can erode the pioneer’s market share - The higher the pioneer's market share in the previous period, the easier it is to erode for the follower - The longer the pioneer's lead-time, the more difficult it is to erode his market share
Tözer, 2010	case study	n.a.	n.a.	1994-2009	Turkey	4	- The dominant pioneer, Turkcell, strengthened its position by strategically delaying regulatory measures (roaming agreements, termination rates, and mobile number portability) and by exploiting tariff-mediated network effects
Lanzolla, Gómez, & Maícas, 2010	linear regression	- Entry order - Market growth - Dummy for UMTS introduction - Former state monopolist - Number of active operators - Interactions between entry order and market growth / UMTS dummy	EBITDA	1998-2007	19 EU countries	65	- Pioneers are more profitable than followers - Market growth has negative effect on profitability - Negative effect of market growth is smaller for pioneers - Introduction of UMTS has negative (positive) effect on profitability of pioneers (followers) - Former state monopolists have higher profitability - Number of operators has negative effect on profitability
Gómez & Maícas, 2011	linear regressions	- Entry Order - Switching costs - Number of active operators - Per capita income	-Market share - EBITDA	1998-2007	19 EU countries	69	- Pioneers have higher market share and profitability - Number of active operators has negative effect on market share and profitability - Switching costs have a positive effect on market share and profitability
Karabag & Berggren 2011	case study	n.a.	n.a.	1994-2009	Turkey	4	- Instead of structural factors, superior management and marketing skills paired with mistakes of competitors enabled the dominant pioneer, Turkcell, to defend and strengthen its dominant position

Table 1 (continued)

	Model			Data			
	Model-type	Explanatory variables	Dependent Variables	Period	Countries	No. of Firms	Core findings with respect to FMAs
Eggers, Grajek, & Kretschmer, 2012	two-step linear regression approach	- Average monthly minutes of use - Number of subscribers to a given operator as share of population - Company fixed effect - Lagged average monthly minutes of use - Lagged number of subscribers to a given operator as share of population - Average revenue per minute of a given operator - Average revenue per minute of competitors - Price of local fixed-line connection - Number of subscribers to competitors as share of population - Number of fixed-line subscribers as share of population - GDP per capita - Share of prepaid consumers in own customer base - Pre-entry experience in same technology - Pre-entry experience in the focal market - Operator is pioneer in 2G - Country launched 2G before 1995	- Average monthly minutes of use - Number of subscribers to a given operator as share of population - Company fixed effect	1998-2004	30	90	- Early entry helps firms with pre-entry experience in the same technology to attract high-usage consumers - Firms with pre-entry experience in the focal market (i.e. incumbent fixed-line operator or 1G operators) achieve higher market shares - Early entrants without pre-entry experience in the same technology achieve higher market shares than entrants with such pre-entry experience
Jakopin & Klein, 2012	linear regressions	- Entry order - Time elapsed since entry of pioneer - Former fixed-line monopolist - ARPU of operator - Price level of operator - Share of revenue from data services - Number of subscribers - GDP	- Market share - EBITDA	2004-2006	49	191	- Pioneers have higher market shares and profitability than later entering operators - Former fixed-line monopolists have higher market share and profitability

By and large, the studies on FMAs in mobile telecommunications support the notion that pioneering network operators enjoy an advantage over their later entering competitors, usually through higher market shares and/or profits. However, as already stated above, the majority of these studies use linear regression models to explain market share dynamics of pioneers and followers. The only two exceptions are the studies of Haucap and Dewenter (2006) and of Bijwaard et al. (2008) which explicitly use a non-linear econometric specification to model network operators' market shares. Since these studies are most closely related to our work, we will describe them in more detail below.

In a regression based on a dynamic growth model in the spirit of Barro and Sala-i-Martin (1991), Haucap and Dewenter (2006) investigate market share dynamics of network operators in 14 EU countries. More specifically, they estimate the following model:

(1) $$\ln\left(\frac{y_{it}}{y_{it-1}}\right) = a_i - b ln(y_{it-1}) + u_{it}$$

where y_{it} denotes operator i's market share in period t, u_{it} denotes a random error term, and a_i and b are the parameters to be estimated. The parameter b in this model can be interpreted as the speed of convergence of operators' market shares to a long-run level. Estimating this model for a sample of 14 European countries for the period 1990-2005, Haucap and Dewenter (2006) find that the convergence of market shares of pioneers and followers is slower in countries that liberalized their market rather late.

In a similar vein, Bijwaard et al. (2008) use a dynamic model derived from Kalyanaram and Urban (1992) to analyze FMAs in 16 European countries. In their study, the market shares of followers are represented by:

(2) $$m_{it} = \gamma_i(1 - e^{-\beta_i t})$$

where m_{it} denotes operator i's market share in period t, γ_i represents operator i's long-run market share, which each operator approaches with a specific speed of convergence, denoted as β_i. Furthermore, γ_i and β_i are modeled as:

(3) $$\gamma_i = e^{\alpha_1 p_i + \alpha_2 p_i^2 + \alpha_3 HHI_i + c_i}$$

(4) $$\beta_i = \beta_1 + \beta_2 HHI_{it} + \beta_3 \Delta p_{it}$$

whereby p_i and HHI_i are the penetration rate and the market concentration at the time of market entry of operator i, HHI_{it} is the market concentration in operator i's market at time t, and Δp_{it} is the change in the penetration rate in i's market since the time of i's entry. Concerning the existence of first mover advantages, these scholars find that for followers

"[…] it is best to enter as early as possible, i.e. it is not optimal to wait with an entry decision" (p. 254) which indicates the presence of first mover advantages for market pioneers.

However, the studies of Haucap and Dewenter and Bijwaard et al. are limited with respect to their internal and external validity. Haucap and Dewenter use the lagged values of market shares to explain the change in market shares in logarithms, without incorporating additional control variables. Bijwaard et al. apply a more elaborate model but their analysis suffers from the fact that, for the period January 1998 to May 2006, it is based on monthly data on market shares and penetration rates, whereas, for the years 1990 to 1997, it relies on annual data which the authors interpolate to monthly data. Moreover, both studies concentrate on the existence of FMAs in European countries. Hence, the question of whether their findings extend to mobile telecommunications markets outside Europe remains unanswered. In our study we address some of these shortcomings by building on the non-linear model proposed by Bijwaard et al. (2008) and refining their analysis in three ways: First, we use a more flexible econometric specification, which is more responsive to fundamental changes in the market structure. Second, our analysis uses a richer data set containing monthly data on market shares and penetration rates from January 1990 to March 2008. Third, we base our estimation on the analysis of the 34 OECD countries, thereby extending the findings of FMAs to countries outside Europe.

III. Sources of first mover advantages in mobile telecommunication markets

From a theoretical perspective, FMAs in mobile telecommunications can stem primarily from three sources (Haucap and Dewenter, 2006; Foros and Steen, 2008): technology-induced cost advantages of the pioneer; demand-side induced disadvantages of followers; and tariff-mediated positive network effects benefitting pioneers.

Technology-induced cost advantages of pioneers

A first reason for pioneering network operators to enjoy a cost advantage over followers is the existence of economies of scale (Gruber, 2005; Foreman and Beauvais, 1999). Owing to the large proportion of fixed costs in setting up and operating a mobile telecommunication network, pioneers can have substantially lower average cost per user as compared to followers if they are able to attract a large customer base before subsequent entry occurs. Moreover, a large customer base enables pioneers to faster realize cost reductions, due to learning effects, which further increase the cost differential between first movers and followers (Whang, 1995; Lieberman, 1989, 1998; Sutton, 1991).

Besides economies of scale, economies of scope can be a second reason for pioneers' cost advantage over followers. In many countries the incumbent fixed-line operator first entered the market for mobile telecommunications (Jakopin and Klein, 2012; see Gruber 2005: 15-21 for some examples). In this case, the mobile network operator can use part of the infrastructure of its parent fixed-line operator, e.g. leased lines or buildings on which transmitters can be built, which will result in significantly lower network operation costs (Haucap and Dewenter, 2006). Furthermore, the mobile subsidiary of a fixed-line incumbent can also capitalize on the existing distribution network and established brand name of its parent. For example, as zu Knyphausen-Aufseß et al. (2002) report, the Greek mobile network operator Cosmote,[3] whose parent company is the Greek fixed-line incumbent OTE, was able to gain a significant competitive advantage by offering its services through the 470 OTE distribution outlets and by capitalizing "especially on the brand awareness and reputation of its parent company" (p. 219). This line of argument is also corroborated by the findings of Jakopin and Klein (2012), Lanzolla et al. (2010), and Sung (2005), who submit that mobile network operators that are former fixed-line incumbents have a significantly higher market share and EBITDA than their competitors.

Thirdly, cost advantages for pioneers in mobile telecommunications arise because of the different technologies employed by pioneers and followers to operate their networks. In the early days of mobile telecommunications, pioneers mainly operated their network in the 900 MHz spectrum, since this spectrum was first assigned for mobile telephony usage. Followers, on the other hand, often operated in the 1800 MHz spectrum (see e.g. Hausman, 2002: 568). While this may have changed over time due to the auctioning of additional licenses, it nevertheless provided pioneers with an initial cost advantage. This cost advantage accrues since transmitters of a 900 MHz network have a greater coverage than those of an 1800 MHz network. As Gerpott (2005) reports, a transmitter operating in the 900 MHz spectrum can cover an area that is 2.3 to 2.8 times larger than that of a transmitter using the 1800 MHz spectrum. Consequently, a 900 MHz network can be operated with a smaller number of transmitters, which, in turn, leads to significant cost reductions for first movers (Gruber, 2005). This cost advantage is further amplified by the fact that the prices or rents for locations where transmitters can be built have been increasing constantly over recent years, making it more expensive for later-entering network operators to roll out their network (Kruse, Haucap, and Dewenter, 2004, p. 81)

[3] Although Cosmote is the third entrant in the Greek mobile telecommunications market rather than a pioneer, it nevertheless exemplifies the fact that mobile subsidiaries of a fixed-line incumbent can benefit to a large extent from their parents' assets.

Demand-side induced disadvantages of followers

Typically, newly introduced products attract those customers with the highest willingness to pay (Kruse, Haucap, and Dewenter, 2004). As Gruber (2005, p. 38) points out, in the case of mobile telecommunications, pioneers primarily "[…] penetrated the segment of high-spending, price insensitive users", enabling them to realize high average revenues per user (ARPU). Hence, when followers enter the market they are only able to attract the mass-market customers with a medium or low willingness to pay, which results in a lower ARPU.

A second demand-side induced disadvantage of followers stems from users' uncertainty about the quality of service of followers. The product 'mobile telephony' can be considered as an experience good (Nelson, 1970), since users can assess important product characteristics, first and foremost network coverage, only ex-post, i.e. after they have subscribed to an operator's network (Haucap and Dewenter, 2006). Nevertheless, the coverage of the mobile network appears to be one of the most important factors influencing a user's decision to join a particular network (Gruber, 2005). Hence, from a user's point of view, joining a follower's network is a somewhat risky decision. Accordingly, users will only switch their network provider if they are compensated by a risk premium, e.g. in the form of subsidized handsets or lower tariffs. However, due to the lower willingness to pay of its customers, a follower's scope for undercutting the price of the pioneer is limited, making it difficult for them to gain users from the pioneer. Instead, followers might find it easier to enlarge their customer base by penetrating new user segments.

Tariff-mediated positive network effects

Positive network effects arise if a user's valuation of a product increases as the total number of its users increases (Shy, 2001, p. 3). In mobile telecommunications, tariff-mediated network effects are of particular importance since they can be endogenously created by network operators through the design of their tariff structure (Laffont, Rey, and Tirole, 1998; see Harbord and Pagnozzi, 2010, and Muck, 2012, for an overview of the literature on on-net/off-net differentiation). Tariff-mediated network effects occur if operators engage in on-net/off-net differentiation, i.e. calls to the own network (on-net calls) are cheaper than calls to a competitor's network (off-net calls). If calls are placed randomly, which is a common assumption in the literature on on-net/off-net differentiation, the probability of making a (cheaper) on-net call is equal to the network's market share. Hence, the utility a user derives from being subscribed to a certain network, ceteris paribus, increases with the number of other users subscribed to the same network, since the average cost per call decreases with the relative size of the network. Therefore, users have a strong incentive to join the largest network in order to minimize their bill and maximize their benefit from tariff-mediated network effects. Since pioneers in mobile telecommunications tend to have higher market shares than followers (Gerpott, 2005; Sung, 2005; Gómez and Maícas, 2011; Jakopin and Klein, 2012) tariff-mediated network effects are highest for users subscribed to the pioneering network, thereby creating tariff-mediated FMAs.

In addition to the strong theoretical arguments supporting the existence of FMAs, the market for mobile telecommunications is also particularly well suited to the analysis of the existence of FMAs: three important conceptual issues concerning the measurement of FMAs discussed in the extant literature, namely endogeneity of the entry decision, definition of the first mover, and bias towards surviving firms, do not apply to mobile telecommunications.

A first concern usually raised in the context of the analysis of FMAs is that in most models market entry is assumed to be exogenous, whereas, in reality, it is reasonable to depict entry as an endogenous decision, driven by characteristics of the market and of the entrant (Lieberman and Montgomery, 1988). However, in mobile telecommunications, market entry is not determined endogenously by characteristics of the market, but exogenously, through a decision of the national regulator to offer additional licenses for network operation (Sarkar et al., 1999; Bijwaard et al., 2008; Fernández and Usero, 2009). The assumption of exogenously determined market entry in mobile telecommunications is also tested by Eggers et al. (2011). More specifically, they test whether those entrants that acquired their license for network operation through a transparent awarding process, like for instance an auction, are more efficient than entrants that acquired their license through a beauty contest or by allotment of the national government. The basic assumption underlying this test is that the more transparent the awarding process, the more likely it is that the most efficient operator will obtain the license. Eggers et al. (2011, p. 16) report that there are "no statistically significant differences between early movers depending on the license awarding method," which the authors interpret as evidence for the exogeneity of market entry in mobile telecommunications.

Secondly, when analyzing FMAs, it is often difficult to unambiguously identify the true market pioneer. Golder and Tellis (1993), for example, point out that in many analyses of FMAs the firms labeled as pioneer were in fact followers, while the true pioneers remained unidentified. This problem may occur if an operator leaves the market too quickly to be observed. In the context of mobile telecommunications, this problem does not arise because every company willing to enter the market and operate a network, first needs to acquire a license. Hence, each active operator and the starting date of its operations are easily observable. Thus, all relevant network operators and the order of their entry can be undoubtedly identified, thereby ensuring that firms first entering the market are correctly labeled as pioneers.

The bias of some frequently used data sets to include only surviving first movers is a third problem associated with the analysis of FMAs (Golder and Tellis, 1993; Day and Freedman, 1990). If the data set contains only surviving companies, the analysis of FMAs is likely to overstate the true effect of being the pioneer in a market. However, this problem does not apply to mobile telecommunications. Due to the formal requirements for market entry, data sets on mobile network operators can be expected to comprise a complete set of all relevant mobile network operators, even if they left the market shortly after their entry. Hence, analyses based on these data sets will not show a "survival bias".

IV. Econometric Model

To explore the existence of FMAs in mobile telecommunications, we rely on an extended version of the dynamic growth model proposed by Bijwaard et al. (2008). The core assumption of this model is that for each follower there exists a long-run market share that operators approach with an individual speed of convergence.

In line with Bijwaard et al. (2008), we assume that the market share of follower i at time t can be expressed as

(5) $$ms_{it} = \gamma_i\left(1 - e^{-\beta_{it} t}\right)$$

with γ_i denoting follower i's long-run market share and β_{it} denoting follower i's rate of convergence to the long-run market share in period t. In principle, it would also be possible to use an alternative econometric specification, e.g. a root function or the functional form developed in Kalyanaram and Urban (1992), to model the empirically observable positive decreasing course of followers' market shares. However, we decided to use the specification of Bijwaard et al. since their model allows for an explicit definition of the factors influencing the two key parameters of a dynamic growth model: namely the long-run market share (steady state) and the rate of convergence.

With respect to γ_i and β_i, we hypothesize that both solely depend on characteristics of the market and not on firm-specific determinants, like for example marketing expenses or product quality. We define the long-run market share, γ_i, as

(6) $$\gamma_i = e^{\alpha_1 pen_i + \alpha_2 pen_i^2 + \alpha_3 HHI_i + \alpha_4 num\_of\_op_i + \alpha_5 num\_of\_op_{it} + \alpha_6 country_i}$$

where pen_i denotes the penetration rate of the market at the time of market entry of company i, calculated as the total number of mobile subscribers divided by the country's total population; HHI_i denotes the Herfindahl-Hirschman index at the time of market entry of company i; $num\_of\_op_i$ contains the number of already active network operators (including the pioneer) in the market at the time of market entry of follower i; $num\_of\_op_{it}$ denotes the number of active network operators at time t; and $country_i$ denotes a series of country dummies.

Although the number of already active operators at the time of market entry is closely related to the HHI at the time of entry, we nevertheless include both variables in our specification for the long-run market share γ_i. This is due to the fact that a certain HHI can be achieved by different combinations of market shares and numbers of firms. For the sake of illustration, consider a simple example where an operator plans to enter a market with an HHI of 0.68. An entrant's odds of successfully entering the market are likely to depend on whether this market concentration is the result of a duopolistic market structure with market shares of 20% and 80%, or whether there is an oligopolistic market structure with 5 active operators having market shares of 2.5%, 2.5%, 3%, 10%, and 82%. Hence, the two variables capture different aspects of the competitive situation at the time of market entry and should therefore be included in the specification for γ_i.

Moreover, we extend Bijwaard et al.'s specification for γ_i to also include the number of currently active network operators in period t. In its original specification, a follower's long-run market share was determined exclusively by characteristics of the market at the time of market entry. Hence, whatever happens after market entry would not affect a follower's estimated long-run market share. However, this assumption is particularly unrealistic if the number of active operators changes after the entry of operator i. For instance, the subsequent entry of an additional network operator most likely impacts the long-run market shares of the other network operators in the market. By additionally including the number of currently active operators in period t, we allow the long-run market share to react to such changes in the market structure, thereby achieving a more realistic representation of reality and a higher fit to the data.

Although including additional dynamic elements in the specification for the long-run market share might appear to be a promising avenue for increasing the model fit, we only include the current number of active operators as a dynamic element in equation (6). This is due to the fact that the basic idea of our econometric model is the existence of a stable long-run market share for each follower in the market. Together, these long-run market shares represent a long-run market equilibrium. Including several dynamic elements in equation (6) would lead to continuously changing predictions for the long-run market shares of each follower, thereby contradicting the key idea of stability inherent in our econometric model.

Furthermore, we define the rate of convergence to the long-run market share, β_{it}, as

(7) $$\beta_{it} = \beta_0 + \beta_1 \mathrm{HHI}_{it} + \beta_2 \mathrm{num\_of\_op}_{it} + \beta_3 \mathrm{del\_pen}_{it}$$

with HHI_{it} denoting the Herfindahl-Hirschman index in the market at period t, $num\_of\_op_{it}$ denoting the number of active operators in the market at time t, and del_pen_{it} denoting the change in the penetration rate since market entry of follower i up to period t.

Plugging (6) and (7) into (5) leads to

(8) $$\mathrm{ms}_{it} = \left(e^{\alpha_1 \mathrm{pen}_i + \alpha_2 \mathrm{pen}_i^2 + \alpha_3 \mathrm{HHI}_i + \alpha_4 \mathrm{num\_of\_op}_i + \alpha_5 \mathrm{country}_i + \alpha_6 \mathrm{num\_of\_op}_{it}}\right) * \left(1 - e^{-(\beta_0 + \beta_1 \mathrm{HHI}_{it} + \beta_2 \mathrm{num\_of\_op}_{it} + \beta_3 \mathrm{del\_pen}_{it}) t}\right).$$

Table 2 provides a list of all variables used in our econometric model together with their definition and operationalization.

From our model we derive seven empirically testable hypotheses. First of all, we hypothesize that the penetration rate at the time of entry exerts an inverted u-shaped effect on the long-run market share of a mobile network operator. This implies that, in terms of the penetration rate, there is an optimal level of market penetration that, ceteris paribus, maximizes a follower's long-run market share. If, at the time of entry, market penetration is still very low, the diffusion of mobile telephony is still in its infancy, as only the relatively small segment of "innovators" (Rogers, 1962) has already subscribed to a mobile network. Hence, large investments are necessary to promote the new technology and to tap new customer segments. Due to the high market risk associated with entry in this stage of the market, a potential entrant is likely to make costly mistakes and to be leap-frogged by later-entering competitors. Taken together, entering a market when the penetration rate is still very low might ultimately lead to a lower long-run market share. If, on the other hand, the penetration rate at the time of entry is already high, so that the diffusion curve has almost reached its saturation level, most of the users potentially interested in subscribing to a mobile network have already adopted the technology.

Table 2: Variables of the econometric model

Variable	Definition	Operationalization
ms_{it}	*market share of follower i at time t*	-
γ_i	*follower i's long-run market share*	-
pen_i	penetration rate at time of entry of entrant i	(total number of mobile customers/country's population) in the month prior to market entry
HHI_i	market concentration at time of entry of follower i	Herfindahl-Hirschman index in the month prior to market entry
$num\_of\_op_i$	number of already active operators at time of entry of follower i	total number of active operators (including pioneer(s)) in the month prior to market entry
$num\_of\_op_{it}$	current number of active operators	total number of active operators at time t
β_{it}	*rate of convergence to the long-run market share*	-
HHI_{it}	current market concentration	Herfindahl-Hirschman index at time t
$num\_of\_op_{it}$	current number of active operators	total number of active operators at time t
del_pen_{it}	change in penetration rate since market entry	(penetration rate in t - penetration rate in the month of entry)
t	time index	t=1 in the month of market entry, where market entry is defined as the month in which the operator first shows a non-zero market share

Thus, in order to increase their customer base, new entrants have to rely on gaining customers from their competitors. This impedes followers from quickly building up a large customer base, eventually leading to a lower long-run market share. If, however, the penetration rate is at a medium level where the diffusion of the new technology starts to accelerate, sufficient investments in promoting the new technology have already been undertaken while, at the same time, the number of potential users who have not yet subscribed to a network is still large. Hence, a company entering the market at this stage to build up its own network can focus on convincing new users to subscribe to its network without having to gain customers from its competitors and investing heavily in market development.

This leads us to propose:

> *H1: There exists an optimal penetration rate that maximizes a follower's long-run market share, implying that $\alpha_1>0$ and $\alpha_2<0$.*

Secondly, we postulate that the market concentration at the time of market entry, measured by the HHI, positively influences a follower's long-run market share. A company entering a highly concentrated market faces a situation in which the distribution of market shares is highly unequal, usually with one dominant firm serving a large fraction of the market. In this situation, an entrant is likely to face strong resistance to entry, mainly from this one dominant player in the market. Building on the theory of fringe competition (see Hirshleifer et al., 2005: 231), it is reasonable to assume that it is easier for an entrant to identify potential customers that have either thus far not been served at all or only been served by inferior products, if he mainly has to deal with one big competitor. If, however, an entrant faces multiple strong competitors, the available product space and customer segments are probably already exhaustively occupied by the already active network operators so that it is very challenging for late entering followers to build up a large customer base in the long-run.

Hence, we propose:

> *H2: The higher the market concentration at the time of market entry, the higher a follower's long-run market share will be, implying that $\alpha_3>0$.*

As already stated, as well as the market concentration at the time of market entry, we also included the number of active network operators at the time of market entry, since each variable captures a different aspect of the competitive environment at the time of market entry. Concerning the effect of the number of already active operators at the time of market entry, we assume that, at a fixed level of market concentration, it is easier to enter a market with a smaller number of already active operators. In this case, it is easier for an entrant to identify niches in the product space that are still unoccupied by competitors. Hence, a follower will find it easier to gain a foothold in the market and attract users, eventually leading to a higher long-run market share.

Likewise, we expect the number of currently active operators in a market to unfold a negative effect on a follower's long-run market share. Drawing on the standard model of Cournot-competition where in equilibrium the market shares are inversely related to the number of firms in the market, we expect the number of currently active operators to exhibit a negative effect on a follower's long-run market share. Besides, by definition, the long-run market shares of the already active operators must be reduced if an additional network operator enters the market with a non-zero market share, since all long-run market shares must sum up to one.[4]

Besides, the empirical literature on FMAs in mobile telecommunications also supports the notion that the number of active operators negatively affects followers' market shares (Sung, 2005; Gómez and Maícas, 2011).

This leads us to propose:

> *H3: The higher the number of already active network operators at the time of market entry, the smaller a follower's long-run market share will be, implying that* $\alpha_4<0$.
>
> *H4: The higher the number of currently active operators in a market, the lower a follower's long-run market share will be, implying that* $\alpha_5<0$.

While the concentration at the time of market entry is assumed to exert a positive influence on a follower's long-run market share, we hypothesize that the current market concentration will negatively affect a follower's rate of convergence to the long-run market share. Especially in the case when the already active operators engage in on-net/off-net differentiation, consumers have strong incentives to subscribe to the larger networks of the already active operators, due to the existence of tariff-mediated network effects, instead of subscribing to the smaller network of a new entrant. The more concentrated the market is, the stronger these network effects, since high market concentration in the mobile telecommunications industry mostly implies that the market is dominated by one or two very large networks. Hence, upon entering a concentrated market, followers will initially find it very hard to attract consumers and to increase their market share, as subscribers to their networks do not enjoy tariff-mediated network effects. This, in turn, negatively affects followers' rate of convergence to the long-run market share.

This argument is also supported by the study of Fernández and Usero (2007) who report that followers find it difficult to grow their market share relative to the pioneer if the market is concentrated. Furthermore, Fernández and Usero (2009) submit that market concentration has a negative effect on the market share growth of mobile network operators.

Hence, we posit:

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[4] Note that we only include followers in our analysis and, hence, we do not include pioneers in our estimation. Therefore, it would in theory be possible for the long-run market shares of the followers to remain constant, even if an additional operator enters the market. This would be the case if the entrant exclusively attracts customers from the pioneer. However, since this is a purely hypothetical scenario, we do not give it further consideration.

H5: The higher the current market concentration, the lower a follower's rate of convergence to the long-run market share will be, implying that $\beta_1 < 0$.

Likewise, we expect the number of currently active operators in a market to negatively affect a follower's rate of convergence to the long-run market share. Typically, the number of active firms in a market is taken as a proxy for the intensity of competition. If there is intense competition among the mobile network operators in a market, it is more difficult for a single firm to increase its market share at the expense of its competitors. Hence, intense competition will negatively affect the convergence rate of all operators that are active in the market. As already mentioned above, empirical findings from the studies of Sung (2005) and Gómez and Maícas (2011) show that the number of active operators negatively affects followers' market shares and therefore also their market share growth. If the number of active operators is interpreted as the entry order (which is a valid assumption in the absence of market exits), additional empirical support for the detrimental effect on followers' market share growth is provided by the studies of Fernández and Usero (2007), Gómez and Maícas (2011), and Jakopin and Klein (2012).

Therefore, we argue:

H6: The higher the number of currently active operators in a market, the lower a follower's convergence rate towards the long-run market share will be, implying that $\beta_2 < 0$.

If pioneering network operators enjoy an FMA as compared to their competitors, they should find it easier than their competitors will to attract consumers who newly enter the market for mobile telecommunications. Accordingly, we expect the change in penetration rate since market entry to exert a negative influence on a follower's rate of convergence. Typically, changes in the penetration rate reflect market growth and increasing market volume (in terms of number of subscribers). If FMAs exist in mobile telecommunications, pioneers will be able to attract a large fraction of all users who subscribe to the network for the first time, which, in turn, will slow down a follower's growth in market share.

This leads us to postulate:

H7: The higher the change in the penetration rate since market entry, the lower a follower's rate of convergence to the long-run market share will be, implying that $\beta_3 < 0$.

Table 3 summarizes our hypotheses concerning the determinants of a follower's long-run market share and rate of convergence to the long-run market share.

Table 3: Summary of proposed hypotheses

		Variable	Proposed Effect
long-run market share			
	H1	Penetration rate at market entry	inverted u-shaped
	H2	HHI at market entry	positive
	H3	Number of active operators at market entry	negative
	H4	Current number of active operators	negative
rate of convergence			
	H5	Current HHI	negative
	H6	Current number of active operators	negative
	H7	Change in penetration rate since entry	negative

V. Empirical analysis and discussion

Description of the data used

To analyze the existence of FMAs in mobile telecommunications we use data from 34 OECD countries covering the period from January 1990 to March 2008.[5] The data set contains penetration rates, market concentration, and market shares (including prepaid subscribers) of 173 network operators that operate their own mobile networks. The subscriber base of mobile virtual network operators (MVNOs) is added to the respective network a given MVNO relies on for providing its service. The data was recorded on a monthly basis for the entire observation period. We excluded the USA from our analysis due to the unique manner in which the Federal Communications Commission (FCC) awarded licenses for mobile network operation (Parker and Röller, 1997). With the introduction of mobile telephone services in the US, the FCC divided the country into 305 non-overlapping regional markets and issued two licenses for network operation in each market. Although, over time, some of these 305 regional duopolies may have become integrated markets, it is unreasonable to treat the USA as a single market for mobile telecommunications. Since our data set does not account for the fragmented market structure of the USA, we refrained from using the data for the US in our estimation.[6]

[5] We are grateful to Informa UK limited for provision of the data.

[6] As a check for robustness, we also estimated our model including the data for the USA which, however, led to similar results.

Prior to the analysis, we corrected the data set for mergers of mobile network operators. This is crucial for our analysis, because otherwise discrete jumps in the market share of one firm would occur if two or more operators merge to a single firm. This, in turn, would negatively influence estimation results. The same holds true if the merging firms form a new operator, which, if ignored, would then be treated as an operator newly entering the market. To identify possible mergers, we searched the data set for discrete jumps in the market share of more than 5%. While this allowed us to identify a total of 12 mergers (detailed information available upon request), we are aware of the fact that we might miss those mergers that result in a change of market shares of less than 5%. However, we believe that this will not significantly affect our estimation results, since changes in market shares in the range of 5% also occur in the data set due to competitive forces.

In principle, there are three possible approaches to deal with the merger of two or more companies. Firstly, it would be possible to ignore the merger. However, as explained previously, this might be detrimental to our estimation results. Secondly, we could simply delete the merged operator, but this has the drawback that we would lose all post-merger information in our analysis. The third approach to deal with mergers among network operators is to sum the market shares of the merging operators for the pre-merger period. While this implies losing the within-fluctuation of market shares of the merging operators in the pre-merger period, summation of market shares still preserves the information from the post-merger period. After weighing the pros and cons of each approach, we decided on summing the market shares of the merging operators for the pre-merger period, since this approach preserves as much information as possible while avoiding merger-induced jumps in market shares.

Furthermore, we also identified the pioneering network operator in each country and excluded it from the data set, since our analysis focuses on the market shares of followers. We considered all those operators as pioneers that either were the first to show a non-zero market share in a specific country or already had a non-zero market share in the first month of observation.

After correcting for mergers and deleting the pioneers, our data set contained 90 followers from 33 OECD countries. On average, a follower is observed for 109.7 months. Table 4 contains additional information on the distribution of followers across the 33 countries.

Table 4: Distribution of followers across countries

	Maximum number of active operators	observation period (t) min.	avg.	max.
Australia	5	14	114.5	178
Austria	5	59	102.7	136
Belgium	3	109	124.0	139
Canada	7	126	143.0	160
Chile	4	16	124.8	208
Czech Republic	4	11	81.7	137
Denmark	5	54	120.0	184
Estonia	4	9	99.3	158
Finland	4	118	151.0	184
France	3	142	142.0	142
Germany	4	114	155.7	187
Greece	4	61	90.5	120
Hungary	3	100	134.0	168
Iceland	3	4	61.5	119
Ireland	4	31	83.3	133
Israel	4	111	143.7	160
Italy	4	29	86.8	148
Japan	5	1	83.5	166
Korea	6	90	114.0	126
Luxembourg	3	35	77.0	119
Mexico	10	88	126.8	178
Netherlands	5	110	130.5	151
New Zealand	2	175	175.0	175
Norway	3	12	93.5	175
Poland	4	13	96.3	139
Portugal	3	115	149.5	184
Slovak Republic	3	14	74.5	135
Slovenia	3	6	56.7	109
Spain	4	16	92.3	150
Sweden	6	3	95.2	184
Switzerland	4	34	84.0	112
Turkey	4	85	140.3	169
UK	5	61	134.3	175

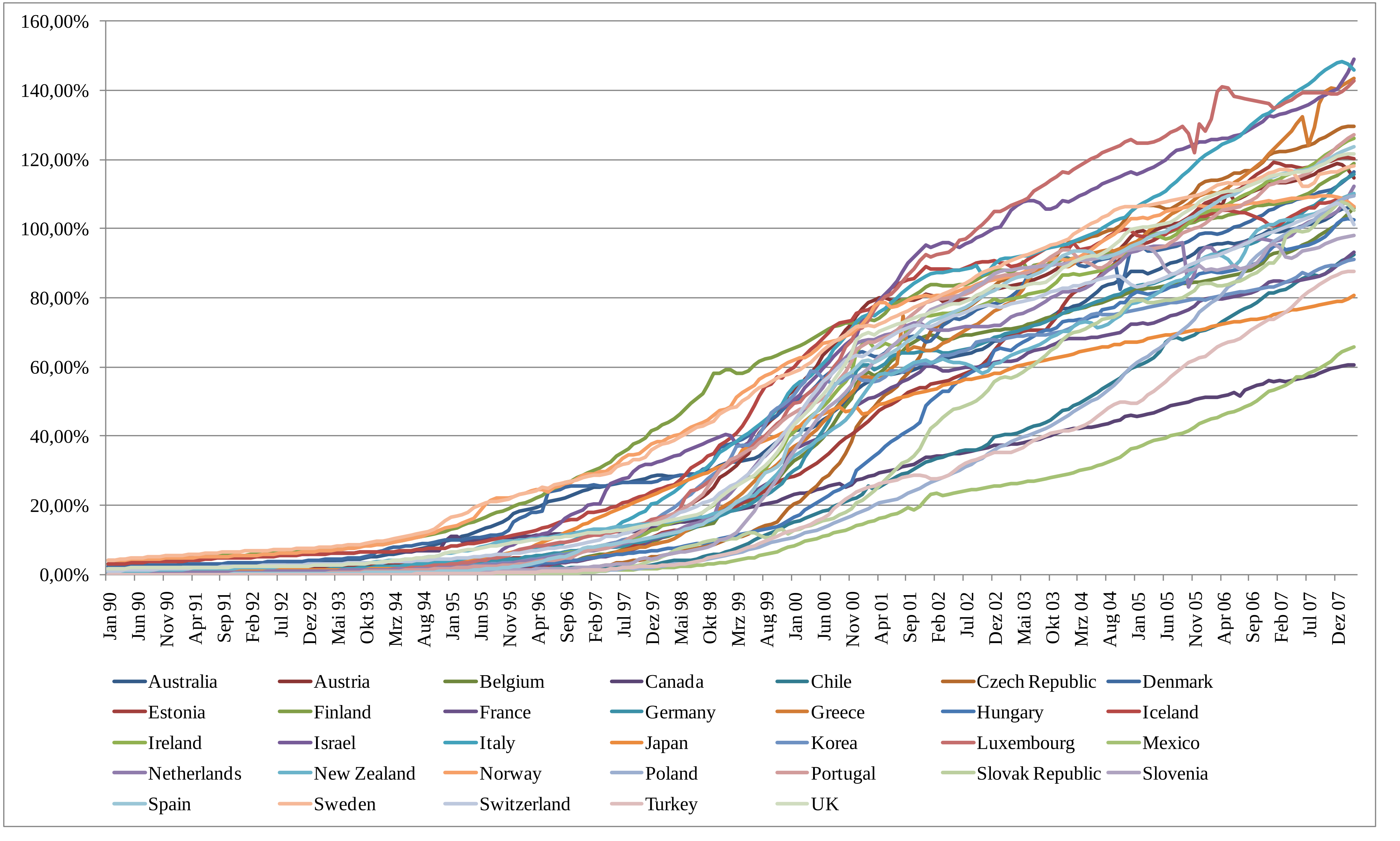

Figure 2: Penetration rates of 33 OECD countries for the period January 1990 - March 2008

The diffusion pattern of mobile telecommunication, expressed by the development of the penetration rates, varies among the countries in our data set, as can be inferred from figure 2. While some countries, for instance Canada, Iceland, Norway, and Sweden, already show comparably high penetration rates in the range of 3-4% at the beginning of our data set, other countries, primarily from Eastern Europe, show substantial lags in penetration rates. However, during the observation period, most countries manage to catch up so that the average penetration rate at the end of our sample (in March 2008) is 111%, with Canada showing the lowest value for the penetration rate (61%) and Israel showing the highest value (149%).

Operationalization of variables

For each operator, we defined the time of market entry as the first month in which the respective operator shows a non-zero market share in the data set. Furthermore, we operationalized the values of the penetration rate and the HHI at market entry as the respective values from the month prior to market entry. The number of active operators at market entry comprises all operators observed in the data set at the month of market entry, including the pioneer(s) but excluding the entering firm. We computed the change in penetration rate since market entry as the difference between the current penetration rate in the respective month and the penetration rate in the month of entry (note that this is not the penetration rate at market entry).

Results of estimation

Prior to the estimation of our model with nonlinear least squares (NLS), two problems must be solved. These are, first, the endogeneity problem arising from the simultaneity of market shares, penetration rates, and market concentration; and, second, the identification of suitable starting values for the NLS routine.

In our analysis, we use both the penetration rate and the market concentration to explain the market shares of followers. This raises the concern that our analysis might suffer from an endogeneity-bias due the fact that a follower's market share also influences, at least partially, the penetration rate, as well as the concentration in the respective market. In order to solve this simultaneity problem, we used the lagged values for the current market concentration (HHI_{it}), current number of active operators ($num\_of\_op_{it}$), and the change in penetration rate since market entry (*del_pen*$_{it}$). Since our data set comprises monthly data, we decided to use a lag length of 12 months in our estimation to obtain unbiased results.[7]

A second problem that must be solved prior to the estimation is the definition of suitable starting values. Due to the iterative optimization nature of the NLS routine, the algorithm needs a set of starting values for all estimation parameters. Since there is no generally agreed rule for identifying the best set of starting values (Davidson and MacKinnon, 2004, p. 232-233; Greene, 2008, p. 294), we tested three different specifications. First, we used the estimation results from Bijwaard et al. (2008) as starting values, with the values for the country dummies set to -1. Second, we set the absolute value of all starting values to 1, but with the signs according to the results of Bijwaard et al., while in the third specification we set all starting values to 1. While specifications one and two lead to similar results, the number of iterations until convergence of the estimation differed. Specification one converged after 58 iterations, whereas specification two needed 72 iterations. For specification three, the NLS routine did not compute estimations for the variables defining a follower's rate of convergence; therefore it was dismissed. Since the number of iterations until convergence can be interpreted as a measure of goodness of fit (Ratkowsky, 1990, p. 21-23), we decided to use specification one in our estimation.

In total, 8,827 observations were entered into the estimation, which resulted in an adjusted R^2 of 0.9213. Due to the use of lags, only the observations for 83 followers were entered into the estimation. The coefficient estimates, as well as the corresponding heteroscedasticity-robust standard errors and p-values are displayed in table 5. Note that, in order to enhance readability, table 5 only incorporates the unweighted mean of the coefficient estimates for the country dummies and their standard error. The complete set of estimates for the country dummies is listed in table 6 in the appendix.

As can be inferred from table 5, all variables are highly significant at the 1%-level. As with other nonlinear models, e.g. binary choice models such as logit and probit, the coefficients of a nonlinear least squares estimation can only be interpreted in terms of their sign but not their magnitude. In Principle, this problem could be solved by computing the marginal effects of the variables. However, in the present analysis, computation of marginal effects would not be very informative, as our model includes 33 country dummies.[8] Hence, the main focus of our

[7] We also estimated our model with a lag length of six months and without lags, but this did not change our results.

[8] In nonlinear models, the marginal effect of one variable also depends on the values of all other variables. Hence, marginal effects are typically calculated by fixing the remaining variables at their mean. In our case, fixing the 34 country variables at their mean would not lead to meaningful results.

analysis is on the sign of the coefficients, because these coincide with the sign of the marginal effects.

Table 5: Estimation results

	Coefficient	Robust Std. Error	p-value
long-run market share			
penetration rate at market entry	1.366	0.176	0.000
penetration rate at market entry squared	-3.053	0.218	0.000
HHI at market entry	0.807	0.074	0.000
number of active operators at market entry	-0.296	0.023	0.000
current number of active operators	-0.075	0.006	0.000
country dummy (average)[a]	-1.228	0.304	-
rate of convergence			
current HHI	-0.101	0.006	0.000
current number of active operators	-0.004	0.000	0.000
change in penetration rate since entry	-0.046	0.002	0.000
t	0.125	0.006	0.000

[a]computed as the nonweighted average of all 33 coefficients.

In line with H1, the penetration rate at the time of market entry has a positive but decreasing effect on a follower's long-run market share. In addition, the market concentration at the time of market entry, measured by the HHI, inflicts a positive effect on the long-run market share, thereby providing support for H2. As proposed by H3 and H4, both the number of already active firms at market entry and the number of currently active operators negatively influence the long-run market share of followers. Besides, all country dummies are estimated to have a significant negative effect on the long-run market share.

Moreover, the results of our empirical analysis confirm H5 and H6 with the current market concentration, again measured by the HHI, as well as the current number of active operators negatively affecting a follower's rate of convergence to the long-run market share. Likewise, the change in market penetration since entry has a decreasing effect on the rate of convergence, supporting H7. Finally, we observe that the market shares of followers tend to increase over time, as indicated by a significant positive coefficient estimate for t.

In order to test the sensitivity of our results to changes in the specification of our econometric model, we performed several robustness checks, none of which led to any changes in the sign or significance level of the estimated coefficients. As a first check, we varied the length of the lags on the variables HHI_{it}, $num\_of\_op_{it}$, and del_pen_{it} and estimated our model using a lag length of six months and without lags. As a second check, we varied our approach for dealing with the identified mergers during the observation period. We estimated our model using a data set in which we deleted the merged operator after the merger and a data set in which we ignored the mergers altogether. Finally, we also included the USA in our estimation as a third check for robustness, which also did not influence our results.

To illustrate the high model fit, figure 3 shows the actual and predicted market shares of followers in selected countries, namely Iceland, Hungary, Germany, and Australia. These four countries were selected for two reasons. First, these countries are rather heterogeneous, for instance with respect to topography, culture, or population density. Second, the number of followers varies among these four countries. While in Iceland, for almost the entire observation period only one follower was active in the market (and, hence, a duopoly existed), in Hungary, two followers entered the market. The German mobile market has seen the entry of three followers over time, while in Australia a total of four followers began operations although, according to our data, one operator was active for only 14 months. Note that the predicted values shown in the four graphs are based on the model without lags, because otherwise it would not have been possible to compute the predicted values for the first 12 months after market entry. The actual market shares of each operator are represented by bold lines, whereas the predicted market shares are represented by dotted lines.

The four graphs provide two interesting insights. First, the graphs demonstrate that our econometric model fits the actual course of the market shares fairly well, irrespective of how many followers are active in the country. In particular, the predicted long-run market share of each follower decreases whenever additional entry occurs, and increases if an operator leaves the market. Second, figure 3 demonstrates that those followers that entered the market earlier usually also have higher market shares than the later entering ones. Hence, it seems that the inverted u-shaped effect of the penetration rate is strictly dominated by the negative effect of the number of already active operators at the time of market entry: although the first followers in most countries entered at very low penetration rates, they nevertheless gained higher market shares than those that entered the market at a later stage.

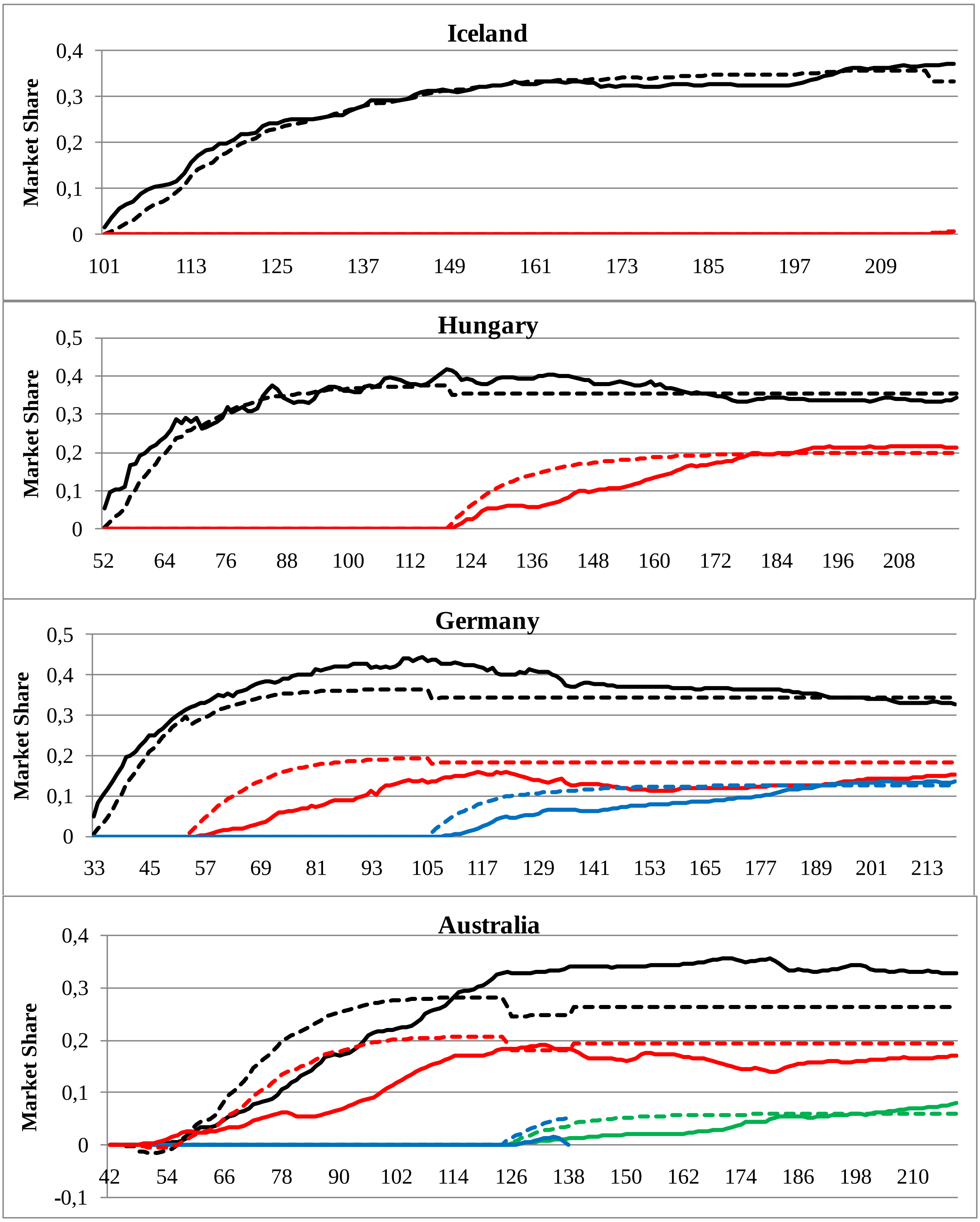

Figure 3: Actual and predicted market shares of followers in selected countries (actual market share bold; predicted market share dotted line)

Discussion

From our analysis of 90 mobile network operators from 33 OECD countries for the period January 1990 to March 2008, three key insights into the nature of FMAs in mobile telecommunications can be inferred.

A first interesting conclusion emerging from our analysis is that the change in penetration rate since market entry negatively affects a follower's rate of convergence to the long-run market share. This result contradicts the findings of previous studies in the mobile telecommunications industry. In their study on central European countries, Fernández and Usero (2007, 2009) report that market growth increases followers' ability to erode pioneers' market shares and to gain market share themselves. While the coefficient estimates for the variable capturing market growth are only significant at the 10% level, the deviating results may be due the fact that Fernández and Usero use linear models, which are not able to adequately account for the nonlinear course of followers' market shares. Furthermore, studying 16 European countries, Bijwaard et al. (2008) find that the change in penetration rate since market entry has a positive effect on followers' rate of convergence. Nevertheless Bijwaard et al. conclude that "there is clear evidence of early mover advantage, mainly caused by the influence of the penetration rate" (2008, p. 246), which in our view is a contradiction to their finding that market growth is beneficial for followers. If the market is growing, i.e. the penetration rate increases as new subscribers enter the market, FMAs should enable pioneers to attract a disproportionately large fraction of the newly entering subscribers, which would, in turn, negatively affect followers' market share growth. Since our finding of a negative effect of the change in the penetration rate since market entry on followers' rate of convergence also holds when we re-estimate Bijward et al.'s original specification, the discordance in results may be attributed to Bijward et al.'s interpolation of the data for the period 1990-1997.

In our view, the finding that market growth, represented by change in the penetration rate since market entry, negatively affects followers' rate of convergence to the long-run market share strongly suggests that FMAs exist in the mobile telecommunications industry. As can be inferred from figure 2, the penetration rates in almost all OECD countries were monotonically increasing during the period of 1990 to 2008. Large changes in the penetration rate are thus typically the result of a rapidly expanding market. Hence, the negative impact of changes in the penetration rate on a follower's rate of convergence implies that a growing market puts followers at a disadvantage as compared to the pioneer. This can be explained by the existence of FMAs that enable pioneering network operators to attract a large fraction of those users who subscribe to a mobile network for the first time. As a result, the fraction of new customers that followers are able to attract is reduced, which then decelerates their market share growth.

Second, our results show that the penetration rate at the time of market entry has an inverted u-shaped effect on a follower's long-run market share. This result is in contrast to the findings of Bijwaard et al., who report that the penetration rate at the time of market entry has a negative, nonlinear impact on followers' market shares. However, analogous to our findings for the change in the penetration rate since market entry, the inverted u-shaped effect still holds if we re-estimate Bijwaard et al.'s original specification. Hence, the differing findings might be attributed to differences in the granularity of the data for the period 1990-1997.

However, we also find that this inverted u-shaped effect is dominated by the negative effect of the number of already active operators at the time of market entry. As a consequence, the first followers in almost all countries have higher long-run market shares than the later ones, although they usually entered the market at low penetration rates.

Together with our finding that large changes in the penetration rate negatively affect followers' growth in market shares, our results imply that it is doubly beneficial for followers to delay market entry until the penetration rate has reached medium levels. According to figure 2, the diffusion process of mobile telecommunication services roughly follows an S-shaped pattern. At low levels of the penetration rate, growth rates are high; however, as soon as the penetration rate reaches medium levels the diffusion curve reaches its inflexion point and growth rates decrease. Hence, if market entry occurs after the inflexion point of the diffusion curve, this will on the one hand maximize the positive effect on a follower's long run market share (due to the inverted u-shaped effect of the penetration rate at market entry) and, on the other hand, attenuate the negative effect of market growth on a follower's convergence rate due to the lower growth in penetration rates.

In essence, our results suggest that there exist two windows of opportunity (Schilling, 2002; Christensen et al., 1998) during which entering mobile telecommunication markets seems particularly promising: either entering the market as the first mobile network operator or entering the market when the penetration rate has reached medium levels. Obviously, in the case of mobile telecommunications, network operators are not able to decide on the timing of market entry, as this is tied to the decision of the national government to issue licenses for network operation. Accordingly, our findings indicate that national governments should wait until the penetration rate has reached a medium level, i.e. after the inflexion point of the diffusion curve, before deciding on whether to issue an additional license for mobile network operation. By doing so, the national governments can provide followers with an optimal starting position and support them in their attempt to gain a foothold in the market.

Third, we observe that although the market concentration, measured by the HHI, and the intensity of competition, measured by the number of active operators, are closely related concepts, they nevertheless have different effects on the market shares of followers. While the intensity of competition reduces both a follower's long-run market share and rate of convergence to the long-run market share, the effect of the concentration rate on market shares is ambiguous. On the one hand, a high market concentration enables followers to ultimately gain a higher long-run market share, but on the other hand, high market concentration decreases followers' rate of convergence, i.e. slows down their growth in market shares. Hence, it is easier for followers to successfully enter the market and build up a large customer base if the market is highly concentrated. However, this requires the followers to exhibit a high degree of perseverance, since market share growth will be slower in highly concentrated markets. Hence, our findings suggest that followers in mobile telecommunications markets should not feel discouraged by initial slow growth rates of their market shares, as these are not necessarily linked to unsuccessful market entry.

VI. Conclusion

In this paper, we explore the existence of FMAs in mobile telecommunications by estimating an extended version of the model developed by Bijwaard et al. (2008). The core assumption of this model is that there exists a stable long-run market equilibrium, which is represented by operator-specific long-run market shares. Operators approach their long-run market share with an individual rate of convergence. By extending the model of Bijwaard et al., we allow the long-run market share to react to major changes in the market structure in the form of market entry and exit.

We derive seven empirically testable hypotheses from our econometric model. Specifically, regarding a follower's long-run market share, we propose, that, first, the penetration rate at the time of market entry has an inverted u-shaped effect (H1). Second, we propose that the market concentration at market entry, measured by the HHI, has a positive effect (H2). Third, we expect the number of already active operators at the time of entry and the number of currently active operators to have a negative effect (H3 and H4). Furthermore, with respect to a follower's rate of convergence to the long-run market share, we hypothesize that, fifth, the current market concentration, measured by the HHI, has a negative effect (H5). Sixth, we postulate that the number of currently active operators has a negative effect (H6) and, seventh, we argue that the change in the penetration rate since market entry has a negative effect (H7).

We test our hypotheses using data on penetration rates, market concentration, number of active operators, and market shares of 90 followers from 33 OECD countries (excluding USA) on a monthly basis for the period January 1990 to March 2008. The results of the nonlinear least squares estimation confirm all seven hypotheses and show that, on average, the market shares of followers increase over time.

With an adjusted R^2 of 0.92, our model shows a high fit to the data, which is confirmed by visual inspection of the actual and predicted market shares of followers in Iceland, Hungary, Germany, and Australia.

Based on our results, three conclusions can be drawn. First, we find that a fast growing market, expressed by large changes in the penetration rate since market entry, significantly slows down a follower's convergence to the long-run market share. In our view, this is a strong indication for the existence of FMAs, which enable pioneers to attract a large fraction of users newly entering the market, thereby slowing down followers' growth in market shares. Second, we find that the number of active operators exerts a negative effect on both the long-run market share and rate of convergence to the long-run market share of followers, whereas the market concentration increases the long-run market share but decreases the rate of convergence. Hence, our results suggest that it is beneficial for followers to enter a more concentrated market, since this results in a higher long-run market share, although with the detriment of slower growth in market shares. Third, the market penetration exerts an inverted u-shaped effect on followers' long-run market share. This implies that, ceteris paribus, there exists an optimal level of market penetration which maximizes a follower's long-run market share. However, the inverted u-shaped effect of the penetration rate is strictly dominated by the negative effect of the number of already active operators in the market: in almost all countries under investigation the first follower gained higher market shares than those that entered later. Nevertheless, this finding might be useful for national governments in deciding when to issue additional licenses for mobile network operation.

We contribute to the literature on FMAs in mobile telecommunications by refining the analysis of Bijwaard et al. (2008) in three respects: First, we use a richer data set, containing a higher resolution with respect to the time dimension and covering a longer observation period.

Second, we expand their analysis of first mover advantages in mobile telecommunications to countries outside Europe by using data on all OECD countries (except for the USA). As a third contribution, we extend their econometric model so that a follower's long-run market share reacts to subsequent market entry and exit. In addition to that, we contribute to the literature on FMAs by being the first to provide a comprehensive overview over the empirical findings concerning the existence of FMAs in the mobile telecommunications industry.

Moreover, our study is also relevant for practitioners concerned with the regulation of mobile network operators. Our findings may serve as guidance for national governments in their decision to issue additional licenses for mobile network operation. We also provide evidence for the presence of FMAs in mobile telecommunications, and hence our results support the asymmetric regulation of pioneering network operators and followers, to provide a level playing field for all market participants.

Several limitations of our study open up avenues for further research. First, despite the fact that our data set in principle exhibits an unbalanced panel structure of 90 operators for a period of 219 months, we did not exploit the panel structure in our analysis. This was because employing panel methods in the context of nonlinear regression models is extremely difficult and subject to numerous pitfalls (Wooldridge, 2002; Greene, 2008). However, future research may find it worthwhile to re-estimate our model using panel methods. Then it would be possible to control for operator-specific unobserved effects, which, in turn, would enhance the explanatory power of our model. Alternatively, it would also be possible to refrain from estimating the model using a one-shot approach and instead apply a two-step estimation strategy in the spirit of Eggers et al. (2012). In the first step, the long-run market shares and the rates of convergence could be estimated directly for each follower. In the second step, the estimated long-run market shares and rates of convergence would then be used as the dependent variables in two separate regressions according to equations (6) and (7). A second limitation of our model stems from the fact that market shares are modeled as solely depending on characteristics of the market, without taking into account the actions of the operators. In a sense, our model conveys a deterministic view with respect to the development of the market shares of followers, since their long-run market share is determined to a large extent by market characteristics at the time of market entry. Therefore a promising starting point for further research might be to incorporate operator-specific actions of the market participants, e.g. marketing expenses or product quality, into the model. To this end, our model could be combined with elements of the model in Kalyanaram and Urban (1992).

The analysis of FMAs in mobile telecommunications is important for national regulatory authorities to adequately design the regulatory regime and to achieve their goal of stimulating competition. We hope our findings will help to deepen our knowledge on the nature of FMAs in mobile telecommunication and will stimulate further research in this area.

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Appendix

Table 6: Estimation results for country dummies

	Coefficient	Robust Std. Error	p-value
Australia	-1.571	0.108	0.000
Austria	-1.244	0.101	0.000
Belgium	-1.432	0.098	0.000
Canada	-1.030	0.105	0.000
Chile	-0.913	0.092	0.000
Czech Republic	-1.163	0.095	0.000
Denmark	-1.397	0.098	0.000
Estonia	-1.591	0.100	0.000
Finland	-1.510	0.102	0.000
France	-1.461	0.085	0.000
Germany	-1.283	0.095	0.000
Greece	-0.540	0.088	0.000
Hungary	-1.315	0.094	0.000
Iceland	-1.474	0.113	0.000
Ireland	-1.248	0.101	0.000
Israel	-1.283	0.124	0.000
Italy	-1.363	0.101	0.000
Japan	-1.040	0.101	0.000
Korea	-0.583	0.144	0.000
Luxembourg	-1.236	0.110	0.000
Mexico	-0.704	0.207	0.001
Netherlands	-1.359	0.098	0.000
New Zealand	-1.251	0.099	0.000
Norway	-1.588	0.101	0.000
Poland	-1.118	0.096	0.000
Portugal	-1.232	0.095	0.000
Slovak Republic	-0.877	0.094	0.000
Slovenia	-1.498	0.111	0.000
Spain	-1.464	0.097	0.000
Sweden	-1.128	0.139	0.000
Switzerland	-1.848	0.115	0.000
Turkey	-0.761	0.096	0.000
UK	-1.015	0.092	0.000

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