# Analyzing competitive effects between fixed and mobile broadband

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## Introduction

The diffusion of mobile broadband, which use cellular mobile communication technology, is at an advanced state in many countries. It is, however, unclear how mobile broadband diffusion affects other broadband services, and fixed broadband access in particular. Following the definition of ITU (2012) we define broadband as a high speed access to the Internet with download speeds of greater or equal to 256 kbit/s. Fixed broadband includes wired technologies such as cable, DSL and FTTH.[1] Mobile broadband enables a non-stationary Internet access based on cellular mobile communication technologies (such as LTE, UMTS or WIMAX).

Competitive effects between different broadband access technologies are of high importance for regulation as well as for competitive strategy: With regard to regulations, technology platform competition can have an effect on the competitive behavior in the individual markets. With regard to competitive strategy, competitive or complementarity effects between different access technologies significantly determine the success of service bundeling strategies.

The goal of our research is twofold. Firstly, want to gain a deeper understanding of how mobile and fixed broadband diffusion affect each other based on the latest country level panel data (ITU 2012, World Bank 2013). A second objective of our research is to deepen the understanding of factors moderating the competitive relationship between fixed and mobile broadband. We therefore present a methodology for moderation analysis and exemplarily demonstrate its application.

The paper is structured as follows. The related research is presented in the following section. The third section addresses the models, data and methodology of analysis. Thereafter, the results of the competition and the moderation analyses are presented and discussed. The conclusions section discusses limitations and next research steps.

## Related Research

Prior research on the competitive effects between fixed and mobile broadband has reached partially contradictory results (Srinuan et al. 2012, Wulf et al. 2013, Lee and Marcu 2011). Srinuan et al. (2012) identify substitution effects between the different technologies. The results of Lee and Marcu (2011) and Wulf et al. (2013), in contrast, suggest a complementary relationship.

[1] Fixed broadband with wireless technologies (such as satellite) have been excluded from the analysis due to simplicity reasons.

Prior research further suggests that multiple factors moderate the relationship between fixed and mobile broadband. Srinuan et al. (2012) analyze price elasticities in various regions in Sweden. They show that broadband coverage and service availability have an influence on competitive effects of different broadband technologies. According to Lee and Marcu (2011), mobile broadband diffusion is affected by standardization policy and population density, but also by the price for fixed broadband access. The latter finding suggests a complementary relationship. Lee and Marcu (2011) further argue that income may play an important moderating role for this relationship. Prior research further suggests that the diffusion level of a traditional technology affects the growth of new technologies (Peres et al. 2010). This aspect may also be applicable to the case of fixed and mobile broadband technologies. Further aspects, which affect broadband diffusion in general (and therefore potentially also competition between broadband technologies) include population age and the percentage of the population living in urban areas (Ford et al. 2008).

## Models, Data and Methodology

To model competitive effects between mobile and fixed broadband access, we use two models: an Extended Bass Model (Peres et al. 2010) and the Lotka Volterra Competition Model (Lee et al. 2005).

The Extended Bass Model bases on the work of Bass (1969), who models the adoption $x_t$ of a durable good at time t, which has been newly introduced into a market. The new purchases $d_t$ at time t can be expressed as follows.

$$d_t = (p+q* x_t/m)*(m-x_t) \qquad (1)$$

The three model parameters are defined as follows:

- The **market potential (m)** is the upper bound for diffusion. A comparison with mobile and fixed telephony services (ITU 2012) suggests that the upper bound for broadband diffusion in a country is oriented at the population size (for mobile broadband) and the number of households (for fixed broadband) respectively.
- **Internal influences (q)** describe the degree to which adoption is affected by interactions between adopters and potential adopters. Bass assumes a linear relationship between the probability, that potential adopters adopt a product, and the existing number of adopters.
- **External influences (p)** describe the degree, to which adoption is affected by aspects other than internal market dynamics (such as marketing campaigns).

Main assumptions of the Bass model are a single market monopoly and a homogeneous and fully connected social network. One area of research in diffusion is the extension of the Bass model for markets with competing brands. In the case of competing brands, the diffusion of a specific brand x is not only affected by within-brand-communication (analog to q in the traditional Bass model) but also by cross-product communication (Peres et al. 2010, Parker & Gatignon 1994):

$$d_t = (p+q*x_t/m_x+s*y_t/m_y)*(m_x-x_t) \qquad (2)$$

The additional parameters are defined as follows:

- The **market potential ($m_i$)** is the upper bound for diffusion of the brand i
- **Cross-product communication (s)** describes the degree to which adoption of a specific brand or product is affected by interactions between potential adopters (delta x) and the adopters y of a different brand or product.

Adopters of a brand can positively communicate about a product category and potential adopters, subsequently, may choose a different brand in the same category. The level of cross-product communication (s) is determined by three different phenomena (Peres et al. 2010):

- Word of mouth: Potential adopters become aware of a category and its utility through communication with other adopters. A potential adopter of mobile access might, for example, be convinced about the general utility of broadband access through communication with a fixed broadband user.
- Signals (Bourdieu, 1984): Potential adopters infer social information from the adoption of a product by other users. With regard to mobile broadband, for example, usage can be associated with a social status of the user.
- Network effects (Goldenberg et al. 2010): The utility of a product for a user increases with the number of users. With regard to broadband access, the utility of a specific access type increases with the number of users of either type.

Cross-product effects do not only occur between substitutes but also between products which do not compete for the same customers. For example, Joshi, Reibstein and Zhang (2009) present a model where adoption in a high status market (sports cars) is interrelated with adoption in a low status market (SUVs). Cross-product effects may also slow down adoption. In the analysis of Joshi, Reibstein and Zhang (2009), adoption in the high status market has positive effects on adoption in the low status market, whereas the reverse effect is found to be negative.

The Lotka Volterra model was originally designed to model the interrelationship between populations in ecology (Leslie 1957). It consists of two difference equations, which model the size of two populations (X and Y) at time t+1 as functions of the population sizes at time t:

$$X(t+1) = \frac{\alpha_1 X(t)}{1+\beta_1 X(t)+\gamma_1 Y(t)} \tag{3}$$

$$Y(t+1) = \frac{\alpha_2 Y(t)}{1+\beta_2 Y(t)+\gamma_2 X(t)} \tag{4}$$

The parameters are defined as follows:

- $\alpha_i$ is the growth parameter for population i and characterizes population growth without limited capacity or competitive influence.
- $\beta_i$ characterizes the capacity for population i ("niche size").
- $\gamma_i$ describes the effect of another population on the growth of population i.

Various researchers have used the Lotka Volterra competition model to analyze competitive effects between products and services (Kim et al. 2006, Kreng and Wang 2009, Wulf et al. 2013).

We used data provided by ITU (ITU 2012) and by World Bank (World Bank 2013) on broadband diffusion and population characteristics. We carried out nonlinear model regressions. For estimation we used the sequential quadratic programming algorithm provided by SPSS. For each model we carried out multiple regressions varying the start values in order to guarantee that global optima were calculated.

A moderator variable generally influences the direct effect between two other variables (Wang and Ware 2013). In this paper we present a preliminary analysis of moderation effects between fixed and mobile broadband diffusion by using the following methodology. After choosing a potential moderator, the data records are allocated into two groups (oriented at whether the value of the potential moderator takes on a value above or below its median). We then separately carry out model regressions for the two groups and compare the results. If the subgroup analyses show differences in the competitive effects, a moderating influence of the focus variable can be assumed. In order to avoid misleading results due to differences in group size (Wang and Ware 2013) we used the median for group separation.

## Competition Analyses

In a first step, we compared the model fit of the Extended Bass Model to the Lotka Volterra Competition Model. An analysis of diffusion data in the different countries shows that the upper bound for diffusion is, for the wireless as well as for the fixed broadband diffusion, above the population and household size respectively. For this reason, the upper diffusion bound was set to 121% of the population size and the household size respectively. This value was derived through an analysis of present diffusion in mature countries and a comparison with telephony (ITU 2013). Regression results for the Extended Bass Model are shown in Table 1.

| Dependent Variable | Determination ($R^2$) | Parameter | Value | Standard Error | 95% confidence interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Fixed Broadband Diffusion | .999 | p | .026 | .003 | .019 | .032 |
| | | q | .197 | .014 | .168 | .225 |
| | | s | -.165 | .017 | -.198 | -.131 |
| Mobile Broadband Diffusion | .952 | p | .016 | .007 | .002 | .030 |
| | | q | .455 | .047 | .362 | .549 |
| | | s | .081 | .031 | .020 | .142 |

Table 1: Extended Bass model regressions (n = 226)

The regressions both have a good fit of $R^2 > .95$. The cross-product communication parameter s takes on a negative value for fixed and a positive value for mobile broadband, both with a confidence of well over 95%. The results imply that a high diffusion level of mobile broadband slows down fixed broadband growth. The reverse effect is positive: a high diffusion level of fixed broadband accelerates mobile broadband growth.

The results for the Lotka Volterra Competition Model are depicted in Table 2. The regressions with the Lotka Volterra Competition Model have an unsatisfactory fit: $R^2$ for mobile broadband diffusion is well below 0.5. Furthermore, the plausibility of the results is questionable. The capacity parameter in the fixed broadband case is set to 0. This implies that there are no capacity limitations. The 95% confidence intervals for the gammas are around 0. As a consequence, no reliable implications can be drawn with respect to cross-product competition.

| Dependent Variable | Determination ($R^2$) | Parameter | Value | Standard Error | 95% confidence interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| Fixed Broadband Diffusion | .992 | alpha | 1.109 | .025 | 1.059 | 1.159 |
| | | beta | .000 | .000 | -1.178E-009 | 1.178E-009 |
| | | gamma | 1.149E-010 | .000 | -1.076E-010 | 3.374E-010 |
| Mobile Broadband Diffusion | .301 | alpha | 20.296 | 5.270 | 9.909 | 30.682 |
| | | beta | 4.408E-07 | .000 | 1.485E-07 | 7.331E-07 |
| | | gamma | -1.562E-08 | .000 | -5.703E-08 | 2.580E-08 |

Table 2: Lotka Volterra Competition Model regressions (n = 226)

With regard to cross-product competition, both models come to the same results. The growth in fixed broadband diffusion is negatively affected by the diffusion of mobile broadband. In other words, the higher the percentage of the population with mobile broadband, the lower the growth in fixed broadband diffusion. One possible explanation is that a certain ratio of mobile broadband users have no demand for a complementary fixed broadband access. In the case of the Lotka Volterra Model, however the results are not reliable.

The Lotka Volterra Model, compared to the Extended Bass model, has a lower fit to the data. This suggests that the Extended Bass Model is better qualified to describe broadband diffusion. For this reason, we only used this model for the following moderator analyses.

### Moderation Analyses

In the following, we exemplarily analyze two potential moderators: gross domestic product per capita and fixed broadband diffusion.

As a first potential moderator we took the GDP per capita (GDPpc) converted to international dollars using purchasing power parity rates in constant 2005 international Dollars. It represents an indicator of the standard of living in a country. As Lee and Marcu (2011) argue, this indicator may have an influence on the competitive relationship between fixed and mobile broadband. The data entries were allocated to one group taking into account whether the GDPpc was below or above the median of 13770.

Table 3 shows the results of the individual regression analyses. All of the four regressions have a good fit of $R^2>0.9$. The cross-product communication parameter (s) for fixed broadband diffusion differs for the high and the low income groups: Whereas in the high income group it has a negative sign, in the low income group it is positive. Since the

95% confidence intervals for these values are both around 0, no significant differences can be identified in the group comparisons.

| Subgroup | Dependent Variable | Determination ($R^2$) | Parameter | Value | Standard Error | 95% confidence interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| GDPpc > 13770 (n=109) | Fixed Broadband Diffusion | 1.000 | p | .058 | .011 | .036 | .080 |
| | | | q | .005 | .023 | -.040 | .050 |
| | | | s | -.007 | .014 | -.034 | .020 |
| | Mobile Broadband Diffusion | .983 | p | .001 | .056 | -.110 | .112 |
| | | | q | .005 | .055 | -.103 | .113 |
| | | | s | .413 | .110 | .196 | .631 |
| GDPpc <= 13770 (n=110) | Fixed Broadband Diffusion | .999 | p | .010 | .004 | .003 | .017 |
| | | | q | .262 | .014 | .235 | .290 |
| | | | s | .017 | .038 | -.057 | .092 |
| | Mobile Broadband Diffusion | .909 | p | .021 | .007 | .006 | .035 |
| | | | q | .471 | .097 | .279 | .663 |
| | | | s | .031 | .030 | -.028 | .090 |

Table 3: Extended Bass Model Regressions with GDP per capita subgroups

| Subgroup | Dependent Variable | Determination ($R^2$) | Parameter | Value | Standard Error | 95% confidence interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| FixedDiffusion > .2903 (n=109) | Fixed Broadband Diffusion | .999 | p | .026 | .003 | .019 | .032 |
| | | | q | .197 | .015 | .169 | .226 |
| | | | s | -.165 | .017 | -.199 | -.131 |
| | Mobile Broadband Diffusion | .953 | p | .010 | .007 | -.004 | .024 |
| | | | q | .441 | .048 | .348 | .535 |
| | | | s | .105 | .031 | .044 | .166 |
| FixedDiffusion <= .2903 (n=110) | Fixed Broadband Diffusion | 1.000 | p | .010 | .002 | .006 | .014 |
| | | | q | .234 | .009 | .217 | .252 |
| | | | s | -.064 | .020 | -.103 | -.025 |
| | Mobile Broadband Diffusion | .828 | p | .044 | .007 | .029 | .059 |
| | | | q | .179 | .096 | -.010 | .369 |
| | | | s | -.100 | .033 | -.167 | -.034 |

Table 4: Extended Bass Model Regressions with fixed diffusion subgroups

The ratio of households provided with fixed broadband access, analogue to the argumentation of (Peres et al. 2010), may affect mobile broadband diffusion because mobile broadband may be regarded as a successor technology. The median for fixed diffusion in our data set was .29, the groups were formed accordingly.

Regression results are presented in Table 4. Model fit in terms of $R^2$ is in three cases above .953, in one case .828. For the mobile broadband regressions, the cross-product communication parameter (s) takes on different signs. The results suggest that if a high fixed broadband penetration is reached, mobile broadband is viewed as a complementary solution. In case of low fixed broadband penetration, in contrast, fixed broadband adoption slows down the growth of mobile broadband penetration.

## Results and Conclusion

In this paper we analyzed the competitive relationship between fixed and mobile broadband and exemplarily showed a method to identify moderators for this relationship. The comparison of two different diffusion models, the Extended Bass Model and the Lotka Volterra Competition Model, showed, that the former has a better fit to the data. The Lotka Volterra Competition Model does not seem applicable for further analyses of this relationship. The application of the Extended Bass Model suggests that mobile diffusion negatively affects growth of fixed diffusion. Fixed diffusion, in contrast, accelerates the growth of mobile diffusion. The further diffusion of one technology, therefore, significantly depends on the current state of diffusion of the other.

The subgroup comparisons allow further insights into the presence and characteristics of moderation effects. The gross domestic product per capita could not be shown to moderate the competitive relationship. A subgroup analysis for the level of fixed broadband diffusion provided valuable implications: in case of a low level of broadband penetration, the growth of both technologies is negatively affected by the diffusion level of the other. In case of a high level of broadband penetration, in contrast, fixed broadband penetration positively affects the growth of mobile broadband penetration.

There are some limitations of the applied models, which need to be addressed in further research. Firstly, market capacities of the two technologies are assumed to be fix and not to overlap. Competitive effects, however, may also be due to an overlap of the market potential. Further research is needed to quantify this overlap to allow a more differentiated specification of upper diffusion bounds.

Furthermore, as stated by Wang and Ware (2013), the identification of moderators through the inclusion of interaction terms into the regression promises results with a higher reliability. In further research, the Extended Bass Model must be adapted to allow such analyses and control for the direct effect of the potential moderator.

Lastly, we only exemplarily showed an analysis of two potential moderators. In further research, other moderators such as price and population density must be looked at.

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