Explaining Telecommunications Performance across the EU

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Executive Summary

The significance of infrastructure industries for the economy

The performance of infrastructure industries, such as energy, communications and transport, has become critical to the performance of our economy and society at large. The performance of the telecommunications industry – including the Internet – has become pivotal, as economic and social activity is increasingly mediated electronically and transacted on-line. Therefore, it is of great importance for policy making to have the appropriate instruments to measure the performance of the telecommunications industry. These instruments should not focus only on providing measurement, like a temperature reading. More importantly, they should provide the means for understanding the underlying cause(s) of the measured performance. Such understanding is vital to evaluate the effectiveness of policy and regulation.

Creating a stylised model of the telecommunications sector

The discipline industrial organization provides a well-recognized stylized model of industry performance: the Structure-Conduct-Performance (SCP) paradigm; the principal ideas were introduced by Mason in the 1930s, it has been formulated as a paradigm by Bain in the 1950s, and has become the basis of Porter's Five Forces Model to analyse industry competitiveness in the 1980s.

The SCP model provides the starting point for our analysis. It is elaborated and modified to reflect the specificities of the telecommunications industry; most importantly, the fact that the industry is subject to regulation. This approach provides several challenges. First, we need to define what actually constitutes 'good' performance. Furthermore, we need to tackle how to measure the level of competition as well as other elements in the SCP-framework. Finally, we need to determine the direct and indirect relationships between all these elements (performance, structure, etc.).

Measuring broadband performance

The typical statistical analysis of the telecommunications industry (and in economics in general) considers a single relationship with one dependent and multiple independent variables. As we are interested in relationships between several (dependent) variables, this type of modelling does not suffice. Moreover, standard techniques are ill-equipped to handle variables that cannot be measured directly, such as performance.

Considering this analytical challenge, the multivariate data analysis technique to be applied is structural equation modelling (SEM). This technique facilitates the detection of patterns within a large set of variables. As such it provides, amongst others, the opportunity to detect patterns between variables that are deemed important for performance. Therefore, it allows us to construct a measure for performance that is data-driven and not based on a single indicator variable or an arbitrary combination of several variables.

Volumes, quality and value for money are measures that are typically associated with performance, in general as well as in the telecommunications markets. However, there are a large number of possible variables that could be used to represent these indicators. On the basis of our statistical analysis of the broadband market, we derived a composite broadband 'Performance Index' that provides the best fit to explain the differences in fixed broadband performance across Europe.

The components of this Performance Index are, in order of importance: (1) the cumulative broadband uptake (across all technology platforms) – this corresponds to the 'volume'; (2) the price (average revenue per user) – representing the 'value' for end-users; and (3) the percentage of households with a data rate at or above 10 Mbit/s on the down link – this variable corresponds to the quality. The weights of these factors are: broadband uptake (% households) at 0.410; prices (Euro) at -0.181; and % lines above 10 Mbit/s at 0.030. The interpretation of these weights is as follows: one extra percent in broadband uptake (or 1 Euro reduction in price, or an additional 1 % of lines > 10Mbit/s) contributes to an increase in the performance index score of 0.410 (or -1.81 or 0.03 respectively).

Factors affecting performance

After having constructed the Performing Index, we assessed which factors play the greatest role in driving positive outcomes. It is noteworthy that *regulation, whilst important, is not the only or even the most significant factor explaining the differences between Member States in fixed broadband performance, as measured by the Performance Index*. This is likely to be due to the considerable success of the EU's Telecoms Regulatory Framework in harmonizing regulatory approaches across Europe. Exogenous factors such as GDP per capita and urbanization are found to play a substantial role. *The most significant regulatory factor influencing outcomes was found to be the price of local loop unbundling (LLU), whereby lower LLU prices are associated with higher broadband performance*. Regulation was found to influence competitive outcomes, but not levels of investment (either positively or negatively). The main results of the analysis follow:

- A prominent finding of the statistical analysis is that *investment levels, expressed per household, are a key driver of broadband performance*. In turn investment levels are primarily driven by GDP/capita, adjusted for purchasing power parity. An increase in GDP/cap by €1000 (corrected for purchasing power parity) is linked to an increase in the Performance Index by 0.736 points. *The analysis does not indicate any linkage (either positive or negative) between regulation and investment levels.*

- *Another most important driver for performance is the level of competition*. Within the analysis 'competition' is captured by a modified Herfindal Hirschman Index (HHI*), which reflects the market shares associated with different competitive platforms (PSTN, CATV, FttX, and the shares of access-based competitors). The influence of the HHI* on the Performance Index is -0.417. This HHI* is in turn driven by the level of LLU prices – as a regulatory input – and by the degree of urbanization. We tested other regulatory factors on competitive outcomes, but the impact of these compared with the level of LLU prices was minor.

- The HHI* is a composite indicator which incorporates both infrastructure-based and access-based competition. We also assessed the impact of infrastructure and access-based competition on broadband performance separately. *The analysis shows that* *the broadband market share of the PSTN incumbent is negatively related to performance, irrespective of the type of competition, i.e. infrastructure-based or access-based*. We also find that in the presence of infrastructure-based competition, typically from cable, market shares for access-based competition are lower.

- Whilst access-based competition tends to take a smaller market share in the presence of cable, our analysis shows that *the combination of infrastructure-based and access-based competition provides the best possible level of broadband performance*. Drawing the conclusion that 'two is enough' for reaching optimal performance, i.e. infrastructure-based competition without access-based competition, is incorrect. This is indicated by the important role that the LLU wholesale price level has on broadband performance.

- The analysis shows that *the LLU wholesale price is the most important regulatory variable in explaining broadband performance, as it influences the market structure*. The indirect influence of the LLU price on the Performance Index is -0.374. This is the second largest driver of performance, after investments. *We conclude that LLU serves as a 'catalyst' for competition, whereby LLU prices are important for LLU-based players to exert pressure on the incumbent players, PSTN and cable alike. Hence, we can conclude that a regulatory regime which favours only infrastructure competition is not enough to deliver strong broadband performance.*

- In the absence of cable as an alternative infrastructure to the PSTN, the only way to achieve competition in an economically viable way is access-based competition.

Implications for next generation access

In the first round of analysis the focus has been on 'basic broadband'. The analysis has shown that attributes relevant to 'next generation broadband' such as take-up of data rates >30Mbit/s are insignificant at this stage compared with attributes relating to basic broadband. This is largely due to the fact that NGA deployment and take-up is at a relatively early phase, which means that there are not yet statistically significant variations across countries. Nonetheless, initial steps in the analysis of 'next generation broadband' have been performed to explore the emerging relationships. While no conclusions can be drawn on the strength of the relationships, an indication can be provided on the direction of the anticipated relationships, which can be tested as additional data on NGA developments becomes available. NGA coverage is defined as the combination of DOCSIS-3 cable coverage, VDSL coverage and FttH coverage.

- In 2011, NGA coverage is foremost determined by DOCSIS-3 based cable coverage: 75% of the NGA coverage is secured by cable alone in the 16 countries covered.

- DOCSIS-3 coverage appears to be linked to greater coverage of other NGA technologies. However, this potential linkage needs to be further assessed as more data becomes available.

- The analysis of the initial NGA data suggests that one hypothesis which could be worth testing is that *a higher intensity of broadband competition, including* *competition from both cable and access-based competitors, may be associated with greater coverage and uptake of NGA*. This may be explained by stronger broadband competition increasing the take-up of broadband at higher data rates, which in turn reduces the risk for NGA deployment. Subsequently, the increasing deployment of NGA enables a higher NGA uptake.

- The analysis of the initial NGA data suggests that a strong performance in 'basic broadband' – measured in terms of high broadband uptake, low broadband retail prices and the prevalence of data rates of >10Mbit/s – is associated with higher NGA coverage, if outlying countries which exhibit a 'grassroots' effect are excluded.[1] Once more data on NGA developments becomes available, it will be useful to test whether this relationship is statistically significant.

- As a potential consequence, as low LLU wholesale tariffs are the main regulatory determinant of broadband performance, which is hypothesized to have a positive association with NGA coverage, the research would also *put into question whether policies to freeze or increase LLU tariffs will result in greater NGA roll-out*.

[1] If all countries are included, the relationship appears to be flat – i.e. without any significant positive or negative relationship.

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Preamble

At the Delft University of Technology (TUDelft), within the Section Economics of Infrastructures, a long-term research program is running, which is aimed at exploring and explaining the differences in performance of broadband markets in the European Union.

This research program has a dual character being both qualitative and quantitative. The qualitative research strand involves the compilation of 12 country case studies by in-country experts. The quantitative research strand is aimed at statistical modelling of the fixed broadband market and the mobile market in the EU-27. This modelling project is targeted at the development of a Telecommunications Competitiveness Index (TCI). This paper reports on the implications of the initial findings of the statistical modelling with respect to fixed broadband.

1 Introduction

The performance of infrastructure industries, such as energy, communications and transport, has become critical to the performance of our economy and society at large. The performance of the telecommunications industry – including the Internet – has become pivotal, as economic and social activity is increasingly mediated electronically and transacted on-line. Therefore, it is of great importance for policy making to have the appropriate instruments to measure the performance of the telecommunications industry. These instruments should not focus only on providing measurement, like a temperature reading. More importantly, they should provide means for understanding the underlying cause(s) of the measured performance. Such understanding is vital to evaluate the effectiveness of policy and regulation.

This contribution is structured as follows: In Section 2 we discuss the definition and measurement of performance, the statistical modelling and the operationalization thereof. In Section 3 we discuss the preliminary model results for fixed broadband. The analysis is summarized with inferences with respect to policy by topic in Section 4. In Section 5 we assess the outlook for next generation broadband.

One of the areas for which we hope to gain greater insight concerns the role of regulation on performance in broadband, and potentially in future the migration to next generation technologies. However, it is important to note, and the analysis confirms, that *whilst relevant, regulation is not the only, or even the more significant factor affecting broadband performance*. We examine its role in a number of contexts, including whether regulation influences investments in the sector and competition.

2 Defining and measuring performance

In assessing performance of the broadband market, league tables play an important role. These tables typically reflect rankings based on broadband penetration in terms of the number of broadband users. However, for a more comprehensive evaluation of the performance of broadband markets it is important to understand the role of the market and the role of governments and regulation in the outcomes that are observed.

Depending on the position taken by governments there is a stronger reliance on either market forces or on governmental support and this applies in particular for fixed broadband. In Japan, for instance, the government provides financial support for Fibre to the Home (FttH) deployment in the form of financing support and tax incentives (Jaag, Lutzenberger and Trinkner, 2009). The Korean government made FttH roll-out a part of industrial policy (Kushida and Oh, 2006; Oh and Larson, 2011). In Australia, New Zealand and Singapore, there has been significant government intervention, both in allocating subsidies for FttX roll-out and in determining the structure and ownership or shareholdings associated with companies supplying high speed broadband (see e.g.: Jaag, Lutzenberger and Trinkner, 2009; Australian Government, 2013; iDA, 2013; New Zealand Government, 2013).

At the other end of the spectrum, in the USA, the Federal Communications Commission (FCC) declared forbearance on unbundling of FttH with the aim to stimulate fibre deployments by incumbent operators (Cornell, 2005; Washburn, 2005). This could be characterized as an extensive reliance on 'market forces'.

In the European Union, the approach towards the broadband market and supply of next generation access has been largely 'market driven', but with adjustments made to incentivise roll-out under the regulatory regime, such as state aid, measures to facilitate the sharing of infrastructure and considerations on the appropriate return on capital for regulated access. In the EU the broadband objectives were originally agreed upon by Member States as part of the Lisbon Agenda (EC, 2000). The realisation of these goals is considered to be primarily the result of the (regulated) market, with state aid in support of rural broadband. These goals were updated with the publication of the Digital Agenda for Europe in 2010 (EC, 2010), which sets ambitious targets for coverage and take-up of high-speed broadband, whilst still refraining from any significant state involvement over and above state aid provided in accordance with DG Competition Guidelines in achieving these goals (EC, 2013). In the reliance on market forces, it is important to assess the functioning of the market in more detail.

2.1 Stylized model of industry dynamics

The discipline of industrial organization provides a well-recognized stylized model of industry performance: the Structure-Conduct-Performance (SCP) paradigm. The principal ideas were introduced by Mason in the 1930s, with Bain having formulated it as a paradigm in the 1950s. The paradigm has become the basis of Porter's Five Forces Model to analyse industry competitiveness in the 1980s.

The SCP paradigm posits that market structure determines the conduct of firms operating in that market, which in turn determines market performance. Mason identified three key determinants for market structure: the concentration ratio of the firms in an industry, the type and degree of product differentiation and the potential entry barriers (Van Gent and Van Bergeijk, 2000). Groenewegen points to the contribution made by Scherer by extending the model to better reflect reality in (1) distinguishing between basic conditions (of supply and demand) as input to the structure; (2) by introducing feedback loops between the various stages of the model; and (3) by emphasizing the strategic behaviour of the actors (Groenewegen, 1989). For an extensive discussion of the SCP paradigm and its evolution see Ferguson and Ferguson (1994); for the broader field of 'new industrial organization' see Church & Ware (2000).

2.2 Statistical modelling

The SCP model provides the starting point for our analysis. It is elaborated and modified to reflect the specificities of the telecommunications industry; most importantly, the fact that the industry is subject to regulation. This approach provides several challenges. First, we need to define what actually constitutes 'good' performance. Furthermore, we need to tackle how to measure the level of competition as well as other elements in the SCP-framework. Finally, we need to determine the direct and indirect relationships between all these elements (performance, structure, etc.).

The typical statistical analysis of the telecommunications industry (and in economics in general) considers a single relationship with one dependent and multiple independent variables. Given that we are interested in relationships between several (dependent) variables, this type of modelling does not suffice. Moreover, standard techniques are ill-equipped to handle variables that cannot be measured directly, such as performance.

Considering this analytical challenge, the multivariate data analysis technique to be applied is structural equation modelling (SEM) (Hair Jr. et al., 2006; Schumacker and Lomax, 2010)[2]. In applying SEM, we follow the process recommendations by Hair et al. Basically, this technique facilitates the detection of patterns within a huge set of variables. As such it provides, amongst others, the opportunity to detect patterns between variables that are deemed important for performance. Therefore, it allows us to construct a measure for performance that is data-driven.

2.3 Operationalization of the statistical model

As the starting position, we applied the basic SCP model and introduced regulation and the institutional environment as elements within the model (see Figure 1). The industry as a whole is affected by the Institutional Environment, while it is hypothesised that regulation may directly affect both Structure and Conduct. The model is focussed on a single industry: telecommunications. The scope is the European Union, and the EU Member States are the constituting parts.

[2] SEM is the only statistical technique that allows for the simultaneous analysis of variables that are dependent in one relation and independent in another relation.

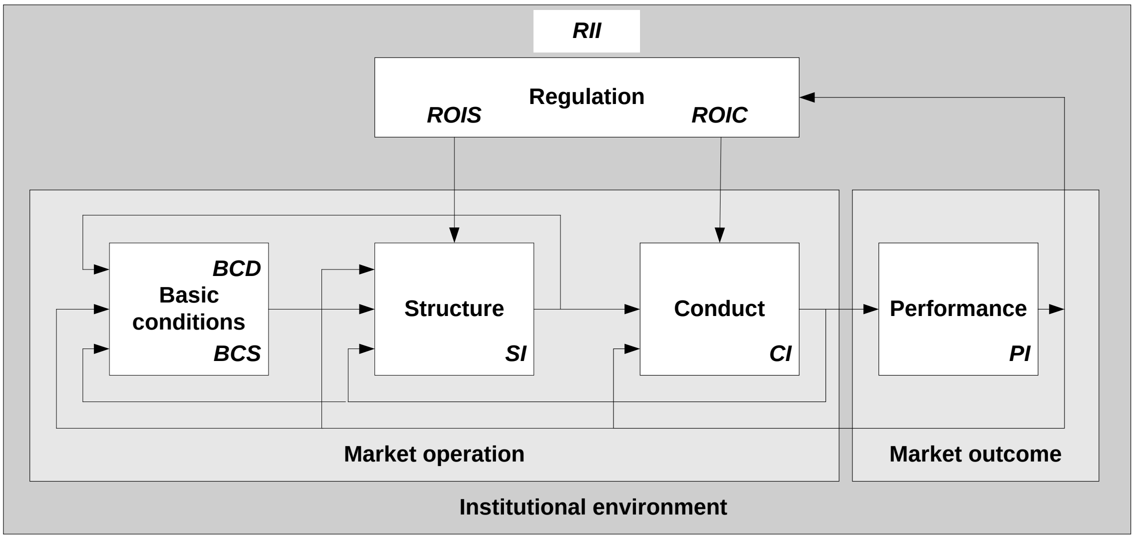

Figure 1. SCP model as applied in the TCI context

Performance is a relative measure as we consider the differences between countries. The research is focussed on determining those parameters that best explain differences in performance, where the SCP paradigm provides the theoretical foundation.

Given the available data we focus on the time period 2008-2011. With such a relatively short time period the possibilities to study dynamics are limited, although potential future applications of the TCI may allow us to consider dynamics in more detail. This will allow, amongst others, to create benchmarks for performance and other elements of the model. These benchmarks are important to study and explain the developments within a country and facilitate the evaluation of policy making on the country level.

In the first application we focus on the fixed broadband market, noting that across Europe in general, substitution between fixed broadband and mobile broadband markets has not been found by national regulatory authorities to be significant.[3]

To capture the various components of the model and to be able to investigate the appropriateness and completeness of the attributes selected to form these components, intermediate variables (indices) have been defined. The first is the *Regulatory Institutional Index* (RII) which is to reflect the institutional environment in which regulators operate. Then there is the *Regulatory Outcome Index*, which is split in two separate indices aimed at capturing the regulatory outcomes that condition the operation of the telecommunications market (directly at wholesale level and indirectly at retail level). In so far the regulatory outcomes impact market structure they are captured in the *Regulatory Outcome Index – Structure* (ROIS). The regulatory factors that impact conduct are captured in the latent variable *Regulatory Outcome Index – Conduct* (ROIC). Next we define a *Structure Index* (SI) capturing elements of the market structure and the *Conduct Index* (CI) containing elements of the behaviour of firms. SI and CI determine the outcome of the market captured by the *Performance Index* (PI).

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[3] Only the Austrian NRA has found that fixed and mobile broadband are substitutes in the retail market for residential customers and refrained from regulating the related wholesale market (Market 5). The Romanian NRA did not regulate Market 5, but this was not driven by mobile substitution but by grassroots fixed broadband deployment in cities.

To this we add the *basic conditions of supply* (BCS) and *demand* (BCD).The main attributes of the indices as derived from the literature are reflected in Figure 2.

Basic Conditions		
Demand	**Supply**	
GDP	Population, incl. density	
Income distribution	Households	
Purchasing power parity	Urbanization	
Regulatory Institutional Index		
Independence	**Accountability**	**Effectiveness**
Political	Procedural	Separate accounts
Operational	Informative	Rights to investigate
Organizational	Discovery	Penalties and fines
Financial	Evaluation	
Regulatory Outcome Indices		
Structure enablers	**Conduct enablers**	
Rights of way/ Infrastructure sharing	Porting of numbers	
Local loop access (unbundling)	Wholesale tariffs	
Spectrum auctions	Contract conditions	
Structure Index		
Market concentration		
Number of players		
Types of networks		
Conduct Index		
Pricing		
Product differentiation		
Infrastructure investments		
Numbers ported		
Performance Index		
Static efficiency (within time period)	**Dynamic efficiency** (across time periods)	
Product volumes	Change in volume	
Prices	Change in prices	
Qualities	Change in qualities	
Costs	Change in costs	

Figure 2. Summary of TCI model attributes by index

Model parsimony

The research aim is to develop a model that is adequate and not over-specified, given that including variables that are conceptually not relevant can lead to several potentially harmful effects (e.g. as multicollinearity increases, the ability to define any variable's effects is diminished). Our model specification is based on economic theory and expert insights. More specifically, theory and experts were used to identify a broad list of variables and constructs that are considered important for the functioning of the telecommunications market. The research is aimed at determining which subset of variables of this extensive model provides a good specification and whether the model can be improved by adding/deleting variables and/or constructs to obtain a more parsimonious model.

2.4 Building the data set

The main source of data for the TCI is drawn from publicly available data bases. We also concluded a comprehensive survey among NRAs complemented by information collected from market players, which is analysed in a separate qualitative report.[4] The data collection took place in the period May 2012 until December 2012. The public data sources used include: EC Digital Agenda Scoreboard, COCOM, Eurostat, ITU, FttH Council, ECTA, Point Topic, Speedtest and ETNO.

We collected data for the EU 27 Member States and Switzerland from data sources up to 2011. The aim was to include all EU countries in the analysis, but the completeness of the data limits this part of the dataset to 16 EU countries: Austria, Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Spain, and the United Kingdom.[5] We gathered data for the period 2003-2012. Due to lack of completeness for certain key variables, the initial analysis focusses on the period 2008-2011.

2.5 Statistical modelling program and terminology

Within this research project the statistical modelling program M*plus* is used.[6] The program provides a wide choice of models, estimators and algorithms. Under the heading Structural Equation Modelling (SEM) this includes two parts: (1) a measurement model; and (2) a structural model.

The measurement model is a multivariate regression model that describes the relationships between a set of observed dependent variables (factor indicators) and a set of continuous latent variables (factors). Performance, for example, is a factor which is estimated by factor indicators, such as broadband penetration and prices.

The relationships are described by a set of linear regression equations for the continuous factor indicators, and a set of probit or logistic regression equations for binary or ordered categorical factor indicators.

The structural model describes three types of relationships in one set of multivariate regression equations: the relationship among factors, the relationship among observed variables, and the relationship between factors and observed variables that are not factor indicators. This part of the model provides, for example, an estimation of the relationship between the 'factors' regulation and structure. These relationships are described also by a set of linear regression equations and logistic regression equations.

There are two types of analysis: exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). EFA is used to detect general patterns between a large set of variables. Basically, EFA is an unrestricted model in which relationships between factor indicators and potential factors are not pre-set. As such it provides directions for assigning variables to certain factors and the number of factors that are underlying the data.

CFA is used to test a specific model. In this case the factor indicators are assigned to certain factors and the potential relationships between those factors are set. The latter

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[4] The data collection process with the NRAs has been facilitated though a dedicated website www.telecompetitivenes.eu.

[5] The inclusion of Switzerland was requested by the NRA. The data on Switzerland is complete with the exception of data to determine the Regulatory Outcome Indices.

[6] For a discussion of the M*plus* program capabilities and their application see the user guide and the library of supporting academic publications on the statistical techniques applied provided at http://www.statmodel.com/glance.shtml.

part is mostly driven by the theoretical SCP framework, e.g., we allow conduct to have a potential impact on performance.

2.6 Exploratory and confirmatory factor analysis – an iterative process

In developing a parsimonious TCI model, an iterative process is applied, moving from exploratory factor analysis to confirmatory factor analysis and vice versa. This process starts with a rudimentary path model and a minimalistic definition of the constructs (PI, CI, and SI). Moreover, the analysis process runs from performance to its constituting parts, i.e., to conduct and structure and to regulation. In each iteration cycle a new variable is added and evaluated in terms of its effect on the particular construct and on the overall model. If the addition adds to the explanatory power and the statistical significance improves or remains the same, the variable is added to the construct and thereby to the model. Subsequently the construct and the model are re-evaluated by assessing the changes of leaving out a variable that was already part of the definition. Again, the deletion is evaluated in terms of its effect on the construct and on the model. If the deletion adds to the explanatory power and the statistical significance improves or remains the same, the variable is removed from the construct and thereby from the model. Otherwise, the variable remains part of the definition. This evaluation is done for all variables that constitute the construct to this point in the analysis. As the model extends beyond two layers the effects become smaller and hence the focus turns to the evaluation of first and secondary effects. Note that in making the modelling effort easier to understand, the process is described as if it was executed step-by-step.

The first round of SEM analysis – covered in this contribution – concerns an in-year and cross-country analysis. In potential subsequent rounds, the analysis could move to in-country and across-years, to be followed by a third round of in-country and across years based on an enhanced path model specification including lagged variables.

3 Data analysis and construction of the fixed broadband path model

In this section we provide our analysis of the data leading to the construction of a parsimonious path model for fixed broadband. This implies determining the factors that constitute the elements of the SCP-model and determining the relationships and weights. These results are preliminary and therefore subject to future change.

3.1 Determining the measure of performance – Performance Index (PI)

Given the difference in broadband performance across the EU Member States, the analysis has been focused on determining those performance attributes that best capture these differences. From the translation of the SCP paradigm to the telecoms model, the generic variables reflecting performance are: (1) volumes; (2) prices; (3) quality; and (4) costs.

Volumes

In the context of broadband, where multiple competing technologies serve the market, several potential measures for volumes exist. We considered the uptake of: xDSL, DOCSIS, FttH and fixed broadband in general, where uptake is expressed by the percentage of households with the relevant subscription. An increase in the uptake of any technology has, *ceteris paribus*, a positive effect on performance. However, the uptake in one technology can have a negative impact on the uptake of another technology. Given these indirect effects, the uptake of fixed broadband in general provides the most consistent measure for performance in terms of volumes.

Prices

The specification of prices is somewhat more cumbersome. Ideally price should reflect the price paid for the product/service consumed, i.e. as an outcome of the pricing and marketing strategies applied by the firms in the competitive market. The alternative is the use of a 'basket of prices as advertised'. This has as drawback the issue of products/services being promoted on the basis of bundles and that prices are varying based on the quality of the offer, in particular the data rates provided. Price as outcome is a constituting part of ARPU, the average revenue per user. However, in ARPU the price is combined with the (bundle of) product(s) and payment for other services, such as equipment rental, installation charges, etc. The analysis shows that the best explanatory power, given the available data sources, is provided by the use of total fixed revenues per broadband connection corrected for the purchasing power. Note that the correction for purchasing power appears to be essential to capture the performance differences properly.

Quality

In the context of broadband, quality has many dimensions. First of all in the form of the data rates provided, at the downlink and the uplink. Secondary, in the quality of the data transfer in terms of: the Rfactor; the average packet loss; the latency; and packet jitter.

Ideally one would use the actual data rates experienced, rather than as advertised. However, this type of data has only been collected very recently and not consistently across the countries covered. A next best alternative is to use the data rates being subscribed to. This type of data is aggregated in four different variables, namely percentage of broadband lines with data rates on the down link above 2, 10, 30 and 100

Mbit/s. Most countries have a penetration close to 100% for lines above 2 Mbit/s. As such this variable is not fit to explain differences between countries. Similarly, the percentages for above 100 Mbit/s are close to zero and do not offer us any insight in differences between countries either. For the other two variables, the 10 Mbit/s variable provides the best model fit. However, we expect that in the near future the 30 Mbit/s variable will give a better model fit. As average data rates subscribed are expected to increase over time, the differences between countries will manifest themselves at increasingly higher data rates. The main benefit of our modelling approach is that the model will find the most relevant indicator for (differences in) quality for the time period under investigation.

The inclusion of secondary quality variables, like Rfactor, was considered but eventually rejected as additional performance attributes for two main reasons. First, the factor loadings (which indicate the relative importance of a variable in determining performance) show that broadband uptake is clearly dominant (0.41) and data rates provide a much smaller contribution (0.03). This implies that the impact of secondary quality variables is becoming insignificant. Secondly, these attributes are rarely considered by consumers in their purchasing decisions.

Costs

Finally, it is difficult to find a good indicator for costs. One of the options that have been explored is the use the total number of Full Time Equivalent employees of telecom operators in a country divided by the number of subscriptions (or households) as a proxy for costs. This variable provided rather incoherent outcomes and also seems to be inconsistent with the other indicators for performance. Data with respect to costs that is provided on annual accounts of operators is typically too aggregated or difficult to compare between different operators. As a result, the cost parameter remains a topic of further study for inclusion in a subsequent update of the TCI.

Outcome of the analysis

The result of the analysis is a Performance Index (PI) composed of three constituting variables. The PI is determined first and foremost by the cumulative uptake of broadband (Standardized Coefficient: +0.937); secondly by the price of broadband subscriptions (price baskets corrected for purchasing power) (Standardized Coefficient: -0.722); and thirdly by the percentage of broadband lines that have data rates above 10 Mbit/s (Standardized Coefficient: +0.494).

NB: The analysis does not suggest that packet loss as a quality indicator is not important, but it does not provide an explanation for the differences in performance between the EU Member States.

3.2 Determining the measure of conduct – Conduct Index (CI)

The SCP model for the telecommunications industry suggests as variables reflecting conduct: (1) pricing behaviour; (2) product differentiation; (3) infrastructure investments; and (4) numbers ported[7].

[7] Note that number portability has an impact on structure when it is introduced, subsequently it becomes a matter of behaviour of the firms with regard to how porting is treated. The level of porting is also an indicator for the intensity of rivalry, hence, it is also evaluated as part of the Structure Index.

First, note that pricing behaviour is not identical to actual observed prices. The first is part of a strategy, while the second is (the observed part of) the realization of such a strategy. Modelling pricing behaviour, including the role of bundling, product strategies, including various forms of entry discounts, and the product differentiation in terms of varying data rates is extremely complex.[8] Moreover, in the TCI model the outcome of pricing behaviour and product strategy is captured through the price of broadband, broadband uptake and data rates as part of the Performance Index. Including a variable that is a proxy for pricing strategies will be highly correlated with our measure for prices in the PI. This would artificially increase the model fit. Therefore, we do not include pricing separately in the CI.

The remaining dimension, investments in infrastructure, has been analysed in detail.

Investments

Investments in infrastructures tend to have a dynamic nature. However, our database only covers a limited number of years for certain key variables. This makes it impossible to model such dynamics at this stage. We considered several (comparative) static (specific year) variables, such as total investments (per member of population and per household) and total investments in the fixed market (per member of population, per household and per telephone line). As we expected, this led to poor model fits due to the variation in investments over the years. Given our current database we decided to filter out the dynamics by calculating the average investments per country over a longer period, namely the average per year investments in the fixed market per household over the period 2003-2011. Note that in the case of fixed broadband, households rather than population is the right denominator, as households are the units served.

Our measure for investments is therefore a proxy for actual investments in a specific year. A dataset covering more years as well as more specific data with respect to fixed investments (for example investments per operator rather than for a whole country) would allow more detailed analysis. This is left for potential future research.

Our measure for investment is found to be significant. It has a strong and positive effect on performance (PI).

Exogenous variables

As the ability to invest and obtain a return through customer services depends on the income of consumers, the link between GDP/capita and investment has also been investigated. A strong and positive relationship with investments and GDP/capita has been found and therefore indirectly a positive impact of GDP/capita on performance. Note that GDP is corrected for purchasing power. Other variables such as urbanization (on CI) and income distribution did not have a significant impact and are therefore not included in the path model.

Impact of regulation on the Conduct Index

Market conduct could also be influenced by the regulatory regime, as this sets the enabling conditions for the operation of the telecommunications market. The regulatory outcomes are captured in relation to two dimensions of the SCP model: (1) structure enablers; and (2) conduct enablers. These enablers are in essence the regulatory

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[8] The investigation by Van Dijk Management Consultants on behalf of the European Commission provides a good view of the complexity involved (Van Dijk, 2011).

conditions that respectively shape the market structure (ROIS) and the firm conduct (ROIC). See also Section 3.3 and 3.4 for an analysis of the regulatory dimension.

Few concrete regulatory indicators are available that could provide a proxy for ‘conduct’. Two that were tested in the context of this research were: porting of fixed numbers and contract conditions which might affect switching. For the latter variable, the data is mainly of a qualitative nature with insufficient grounds to structure this data in quantitative data with dummy variables. Therefore, this variable has not been included in our econometric analysis. Porting of fixed numbers does seem to have a positive relationship with the level of competition (as measured by the HHI*), but its impact is statistically insignificant.

Outcome of the analysis

The Conduct Index construct as adopted includes one constituting variable: average investments in the fixed market per household. One factor has been identified that influences the conduct and is statistically significant: GDP per capita, corrected for purchasing power (Standardized Coefficient: +0.633).

3.3 Determining the measure of structure – Structure Index (SI)

The SCP model for the telecommunications industry suggests as variables influencing market structure: (1) market concentration; (2) number of players; and (3) types of networks.

In the rudimentary path model we started with the Herfindahl Hirschman Index (HHI) measuring the concentration of suppliers as the initial single variable specification for the structure index. The initial findings suggested a positive relationship, which would imply that less competition would lead to a higher performance; a rather surprising result. This led to a choice between two options: (1) to reject that a higher intensity of competition improves performance; (2) replace ‘pure’ operator market shares by an alternative metric. This led to exploring the type of technology upon which competition is based. The detailed analysis of the components constituting the HHI suggests a combined effect of inter- and intra-platform competition. It appears that the presence and size of a competing cable network has a strong positive effect on broadband uptake, on data rates and a negative effect on prices. At the same time the market share of DSL-based intra-platform competition is weaker in the presence of cable. The analysis shows that at the aggregate, i.e. irrespective the type of competition, performance is strongly but negatively related to the market share of the PSTN incumbent. Further analysis suggests that a general HHI of the broadband market, taking broadband shares irrespective of technology platform, needs to be replaced by a HHI* reflecting the competition between platforms rather than between firms, essentially reflecting the HHI of technology platforms and how they are used for service provision.

The HHI* being adopted is the sum of squares of the broadband market share of: (1) the PSTN incumbent operator’s xDSL plus cable (and fibre) where applicable; (2) the cable operator(s)’s DOCSIS-3, exclusive of PSTN incumbent’s share; (3) the full plus shared local loop unbundling (LLU); (4) the share of bitstream plus resale; and (5) the share of fibre plus other technologies. We also tested other variants of a concentration ratio, amongst others: (solely) market share of cable, market share of LLU (in-and excluding shared unbundling), market share of the whole DSL market and various combinations of the technologies in modified Herfindahl-Hirschman Indices. The HHI* as defined above provided overall the best model fit.

As the redefined HHI* captures the differences in technologies it reflects the notion of product differentiation as included in the SCP model. Moreover, the assumption is made that broadband consumers represent individual buyers and hence there is no need to account for possible differences across countries with respect to buyer concentration.

Exogenous variables

Market structure – and thereby the HHI* – is also influenced by the cost conditions of building networks as this can affect the extent to which infrastructure competition is viable. The variable 'degree of urbanization' has been analysed as a proxy for differences in the cost structure. This variable has shown to have a significant effect. High urbanization rates are, for instance, associated with a higher penetration of cable.

Impact of regulation on the Structure Index

With reference to the discussion on the potential impact of regulation in Section 3.2, the HHI* indicator is likely to be influenced by regulation, particularly since it specifically includes competition provided on the basis of regulated access. We therefore analysed two regulatory instruments which might affect the HHI*: (1) rights of way, which affects the degree of infrastructure competition; and (2) local loop access (unbundling), which affects the degree of access-based competition. As wholesale price variables, both the price for full unbundled loops and for shared loops have been evaluated (corrected for purchasing power parity). Once the price for full unbundling is factored in, the price of shared unbundling does not add significant explanatory power. During the period of analysis (2008-2011) LLU was the most significant wholesale access product. Moreover, the price for LLU can be assessed whereas charges for bitstream and resale are more complex. Therefore, we focused on the charge for LLU. The prices for resale and bitstream were not analysed. See also Figure 15.[9]

During the period analysed, there was relatively little differentiation between the countries as regards conditions for rights of way and duct access. Therefore, these variables did not appear as being statistically significant for inclusion in the Structure Index. We cannot exclude that a different outcome might be found in later years if conditions for duct access become more diverse.

Other variables that could be considered conduct enablers are: porting of fixed numbers and contract conditions affecting customer switching. For the latter variable the data is mainly of a qualitative nature with insufficient variability to structure this data in quantitative data with dummy variables. Therefore, this variable has not been included in our econometric analysis. Porting of fixed numbers appears to have a positive relationship with the level of competition, but its impact is insignificant.

Outcome of the analysis

The SI construct as adopted includes one constituting variable: the HHI*, the modified Herfindahl-Hirschman Index based on technology platform shares, adjusted for the PSTN incumbent's share in alternative technology platforms, such as RTV-cable. Two factors have been identified that influence the market structure and are statistically significant: (1) the wholesale price for full unbundling corrected for purchasing power

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[9] See for a longitudinal analysis of access developments (resale – bitstream – unbundling) the conference paper "Unbundling: Regulation is a necessary, but not sufficient condition to reach the final rung of the investment ladder." Presented on June 7, 2013 at the Florence School of Regulation conference "Regulation in an Age of Convergence". (Lemstra and Van Gorp, 2013)

(Standardized Coefficient: +0.348); and (2) the urbanization rate (SC: -0.500). Remember that the HHI* is a negative variable, which implies that a high HHI* is a sign of low competition, such that urbanization has a positive effect on competition and indirectly a positive effect on performance.

Link between SI and CI

The analysis has shown that the link from structure to conduct, i.e., from degree of competition to investment, is ambiguous. This might be due to the lack of specificity of the investment data and the fact that only in-period effects are considered across countries, rather than temporal effects within a country. Another hypothesis might be that different factors pull in different directions. For example greater competition might lead both to a higher degree of infrastructure duplication (in the core network) and to a lesser extent in the access network. However competition may also provide constraints that increase the efficiency of investments.

3.4 Impact of the regulatory institutional environment – Regulatory Institutional Index (RII)

The regulatory institutional environment sets the conditions for the regulatory process and thus the regulatory outcomes, as these set the enabling conditions for the operation of the telecommunications market. These conditions are related to: (1) independence; (2) accountability; and (3) effectiveness.

The data we analysed for the RII comes mainly from the survey amongst NRAs. The questions of interest for this Index are mostly multiple choice questions. For certain questions the answers of the countries were very similar. Hence, these variables characterizing the regulatory institutional environment will not be able to contribute to explaining difference in performance. For other variables such as, for example, state ownership of the incumbent operator, we ran regressions on the constituting parts of the TCI model as presented in the path model. More specifically, we regressed state ownership on the LLU price, on the HHI* and on the performance PI.

Outcome of the analysis

We did not find any significant relationships. One problem is that the use of multiple choice questions has led to relatively small variances in the outcomes for the countries and years studied. Another problem is the qualitative nature of this type of data. In this case, countries might be too different, where each country has a unique story to tell. In order for an econometric analysis to be successful, the countries need to be sufficiently different from each other, but at the same time they must have certain aspects in common. If for example a certain cluster of countries has certain characteristics in common and also has a relatively high performance, then we should be able to establish that this characteristic has a positive effect. Only a more in-depth qualitative study of the various aspects of the regulatory institutional environment may identify the appropriate variables that are significant in explaining differences in the performance between the EU Member States.

3.5 Resulting path model – fixed broadband

The provisional parsimonious path model resulting from the initial round of analysis is reflected in Figure 3.

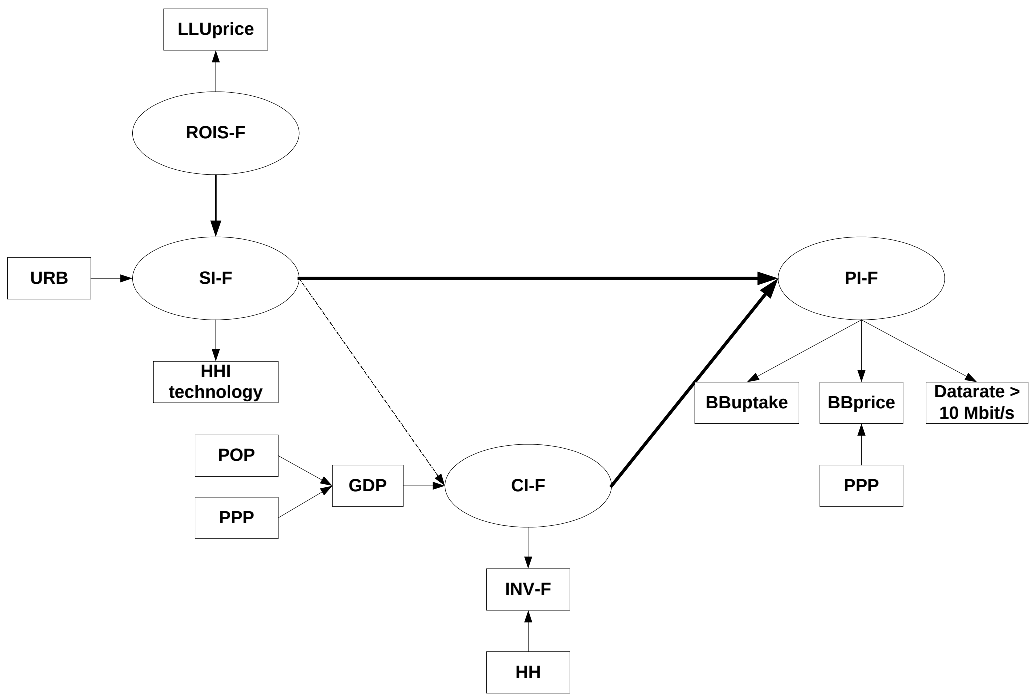

Figure 3. Parsimonious TCI path model - fixed broadband (provisional)

This model has been found to be robust in measuring and explaining the difference in performance across EU Member States using the data for 2008, 2009, 2010 and 2011.

In Figure 4 the results of the analysis are summarized based on Standard Coefficients. Standardized Coefficients (SC), beta coefficients or standardized estimates are the estimates resulting from an analysis carried out on independent variables that have been standardized so that their variances are 1. Therefore, standardized coefficients refer to how many standard deviations a dependent variable will change, per standard deviation increase in the predictor variable. Standardization of the coefficient is usually done to answer the question of which of the independent variables have a greater effect on the dependent variable in a multiple regression analysis, when the variables are measured in different units of measurement (for example, income measured in dollars and family size measured in number of individuals).

Variable	Standardardized coefficient	P-value
Performance Index (3-factor composite)		
Broadband uptake	0.937	0.000
Broadband prices	-0.722	0.000
% lines above 10Mbit/s	0.494	0.011
Conduct Index (1-factor: investment)		
GDP/cap on investments	0.633	0.000
Structure Index (1-factor: HHI*)		
LLU price on HHI*	0.348	0.046
Urbanization on HHI*	-0.500	0.003
Model		
SI on PI	-0.398	0.004
CI on PI	0.757	0.000

Figure 4. Weights of the variables relative to the construct and model - fixed broadband

Within the path model, the Structure Index affects the Performance Index with a Standardized Coefficient of 0.757 and the Conduct Index has a Standardized Coefficient of -0.398. The p-value provides information about the significance of the individual variables in the model. Since all values are below 0.05 we may conclude that all variables are significant at the 5% level.

3.6 TCI path model weights – fixed broadband

As previously outlined, the Standardized Coefficients provided in Figure 4 reflect the relative importance of the individual variables that constitute the composite index and the relative importance of structure-SI and conduct-CI on performance-PI. To arrive at the overall path model outcome, i.e. the effects of all these variables considered together on the performance index-PI, their individual contribution needs to be calculated. This is typically done by a regression based approach. While the literature provides a choice from several techniques, we have applied the standard as provided by the M*plus* statistical program. The results are depicted in Figure 5.

Variable	Direct effect	Indirect effect	Average (2010)
Performance Index (3-factor composite)			
Broadband uptake	0.410		64
Broadband prices	-0.181		€24.88
% lines above 10Mbit/s	0.030		35
Conduct Index (1-factor: investment)			163
GDP/cap on investments (PPP)	13.621	0.736	€17.160 x1000
Structure Index (1-factor: HHI*)			44
LLU price on HHI*	0.896	-0.374	€9.93
Urbanization on HHI*	-0.277	0.116	43
Model			
CI on PI	0.054		
SI on PI	-0.417		

Figure 5. TCI model weights

Interpretation of the weights relative to the Performance Index - PI

The factor analysis as part of the structured equation modelling has identified those variables that determine fixed broadband performance and their respective weights. Only those variables that have proven to be statistically significant have been taken into account in the model.

With respect to the Performance Index (PI), there are three factors that constitute this composite index: broadband uptake (percentage of households); broadband prices; and the percentage of lines with a data rate above 10 Mbit/s. The interpretation of the weights is as follows: one extra percent point in broadband uptake (or 1 Euro increase in price, or 1 % increase in lines having a data rate > 10Mbit/s) increases the Performance Index score by 0.410 points (or -1.81 or 0.03 points respectively).

Interpretation of the weights relative to the Conduct Index - CI

The Conduct Index (CI) is represented by one factor: investment per household. The CI is driven in turn by the level of GDP per capita, adjusted for purchasing power parity. The weight of the adjusted GDP/capita on the CI is 13.621.

Interpretation of the weights relative to the Structure Index - SI

The Structure Index (SI) is represented by one factor: the modified Herfindal Hirschman Index (HHI*), which reflects the market shares of competitive platforms including the incumbent, cable and access-based competitors. The SI is in turn driven by the level of LLU prices and the urbanization rate. The weight of the LLU prices on the SI is 0.896 and of urbanization is -0.277.

Interpretation of the weights relative to the overall model

In the overall model, the Performance Index is driven by the Conduct Index and by the Structure Index, hence by investments and by market structure. The weight of the Conduct Index on the Performance Index is 0.054. The weight of the Structure Index on the Performance Index is -0.417.

On this basis we can derive the indirect impact of investments on the Performance Index: an €1000 increase in GDP/cap, after adjustment for purchasing power parity, leads to an increase of the Performance Index by 0.736 points. Similarly, a 1% increase in the LLU price will lead to a decrease in the Performance Index by 0.374 points. And a 1% increase in the urbanization rate will increase the Performance Index with 0.116 points.

3.7 Validating the model fit – fixed broadband

Figure 6 provides the most important indices reflecting the tests for the 'goodness of fit' for the overall TCI model. The Chi-Square test is a 'positive' test and a good fit result requires that the null-hypothesis is not rejected. This is indeed the case as (at 5% significance) the null-hypothesis is only rejected if the P-value is below 0.05. The literature warns that this test is sensitive to sample size; more specifically, the P-value tends to increase with the sample size. As the TCI sample size is quite small this limitation does not present a problem.

Chi-Square Test of Model Fit	
Value	21.652
Degrees of Freedom	25
P-value	0.6558
RMSEA (Root Mean Square Error of Approximation)	
Estimate	0.000

Figure 6. TCI tests of model fit

Given the above mentioned problem with the Chi-Square test, the RMSEA (Root Mean Square Error of Approximation) test is often used as a replacement. This test statistic is somewhat similar to the R-squared in regression analysis yet in this case the RMSEA must be as low as possible to indicate a good fit. More specifically, it should be below 0.08. With a value of 0.000 this does not present a problem in our case. In conclusion, the TCI model performs well on both fit-indices. However, it should be noted that given the small sample size, the accuracy of these tests is not optimal, which is an intrinsic problem for cases with small sample sizes.

3.8 Performance Index results for fixed broadband

Based on the model estimates, the Performance Index outcome is presented in Figure 7 for the years 2009 through 2011. These figures have been rescaled such that an outcome of 100 represents the average. This rescaling has no effect on the weights, but makes it easier to interpret the outcomes. Latvia and Malta are not included in the table due to the lack of certain relevant data. For the underlying data, please see Annex B.

Country	PI 2009	PI 2010	PI 2011
AT	94*	94	94
BE	106	108	110
BG	79	86	89
CH	94***	94***	94***
CY	97	102	111
CZ	79*	83	87
DE	99	100	102
DK	119	120	119
EE	90	94	96
EL	94	100	103
ES	100	104	106
FI	101*	99*	93*
FR	109*	111	112
HU	85*	88	89
IE	110	112	116
IT	95	98	99
LT	72	75	77
LU	115	114	117**
NL	121*	121*	123*
PL	81*	83*	84*
PT	92*	92*	94
RO	79	79	78
SE	106	107	106
SI	100	101	99
SK	69	73	75
UK	112*	112*	115*

*Missing one data point, which is estimated within the model.
**Using the retail price level of 2010.
***Very rough estimate due to missing data.

Figure 7. Fixed broadband Performance Index by country, 2009-2011

With the weights for GDP/cap and the degree of urbanization being significant but outside the scope of telecommunications policy and regulation the PI results can be corrected for these factors with the results being reflected in Figure 8. The data shows that the relatively high Performance Index of the richer countries can partly be explained by their relatively higher income. Correcting for these two exogenous factors bring the results closer together, although still with some variation.

Country	PI 2009	PI 2010	PI 2011
AT	91*	90	90
BE	102	103	105
BG	86	93	97
CH	88***	88***	88***
CY	94	99	108
CZ	83*	87	91
DE	94	94	95
DK	119	119	118
EE	95	99	101
EL	94	101	105
ES	98	102	104
FI	100*	98*	92*
FR	105*	107	108
HU	91*	94	95
IE	109	112	115
IT	93	96	96
LT	76	79	80
LU	108	107	110***
NL	116*	116*	117*
PL	86*	87*	88*
PT	93*	93*	95
RO	86	87	86
SE	106	107	105
SI	104	105	102
SK	74	78	80
UK	106*	106*	109*

*Missing one data point, which is estimated within the model.
**Using the retail price level of 2010
***Very rough estimate due to missing data.

Figure 8. Fixed broadband Performance Index by country, corrected for GDP and urbanization rate, 2009-2011

4 Summary of the fixed broadband analysis and inferences for policy

As described in the previous Sections, the development of the TCI model is an iterative process aimed at determining the best possible path model description. In the development of the model, various combinations of attributes have been tested to arrive at a statistically significant model. In this Chapter the analysis is summarized and discussed by topic, and based on these summaries initial inferences can be drawn with respect to telecommunications policy and regulation.

4.1 Fixed broadband uptake and the link to the Digital Agenda for Europe

Similar to the adoption of other new technologies, fixed broadband uptake also shows the typical logistic curve (s-curve), see for an illustration Figure 9. Considering the importance given to broadband in economic development, policy is typically aimed at influencing the starting point of broadband uptake – moving it closer in time; influencing the inflexion point – again moving it closer in time; and influencing the rate of adoption – achieving a higher level of adoption more quickly. In this Chapter we will review the outcome of the econometric analysis and show where policy and regulation have shown to have had an influence on broadband performance and where general economic and market factors have played a major role.

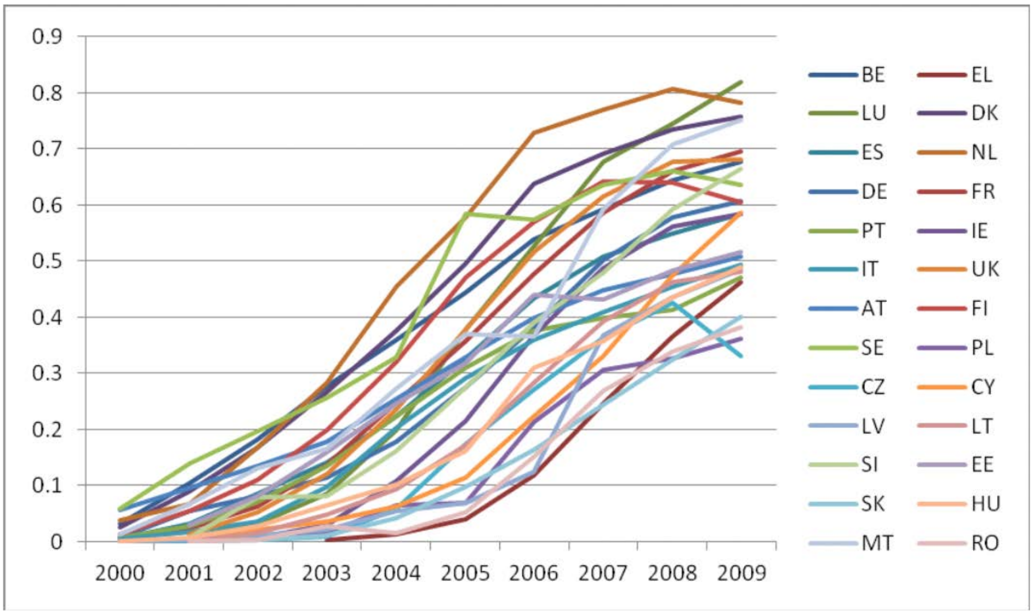

Figure 9. Broadband as share of total fixed lines EU, 2000-2009

The Digital Agenda for Europe (DAE) (EC, 2010) includes in terms of broadband performance three targets, which can be summarized as follows:

By 2013:

- Bringing basic broadband to all Europeans; this is understood as a minimum of 2 Mbit/s on the down-link;

By 2020:

- Ensuring that all Europeans have access to Internet speeds of above 30 Mbit/s and
- 50% or more of European households have subscribed to Internet access above 100 Mbit/s.

The DAE sets targets for coverage and uptake, but does not include end-user prices. This is appropriate as the analysis of relevant markets has shown that, as a matter of principle, regulation of retail prices is not required, given that regulation of wholesale access is considered sufficient to realize a competitive downstream market.

Summary and inferences

In explaining the broadband performance across the EU, a composite indicator has been derived, which is composed of three statistically significant variables. These are in descending importance: (1) the in-year broadband uptake (across all technology platforms) as percentage of households; (2) the price (basket of advertised prices); and (3) the percentage of households with a data rate at or above 10 Mbit/s on the down link. The relative weights of the variables have been determined within the model so as to best explain variations between Member States.

In order to better associate the findings with the DAE, a variant of the model was tested, with the criterion households having broadband with data rates over 30 Mbit/s, conforming to the DAE target. However, with the data from 2008-2011, the criterion 10 Mbit/s was found to be more significant in explaining the difference in performance across countries and hence was included in the model. One may expect that over time the 30 Mbit/s criterion will become more significant as take-up of NGA technologies becomes more prevalent.

4.2 The effect of competition on performance

The analysis shows that a general HHI of the broadband market, taking market shares of the firms irrespective of the underlying access mode (inter or intra-platform) has little explanatory value and needs to be replaced by a HHI* reflecting the type of competition – with a specific distinction between (i) the incumbent, (ii) challengers competing via their own cable or fibre platforms or (iii) challengers competing by means of access through unbundling or bitstream. The best specification of HHI* in explaining performance is the sum of squares of the broadband market share of: (1) the incumbent operator in the fixed broadband market (including its share in cable and fibre); (2) the cable operator(s) DOCSIS-3 (exclusive of incumbent's share); (3) the full plus shared local loop unbundling of entrants; (4) the share of bitstream plus resale of entrants; and (5) the share of fibre plus other technologies (exclusive incumbent's share) of challengers.

This may be interpreted as the potential for different 'technology routes' enabling competitive offerings having more effect on performance than the relative size of each operator. If this hypothesis is correct, it could call into question whether 'consolidation' *per se* would have a positive impact on performance, in comparison with markets in which there are a larger number of access-based entrants each with a smaller presence, thereby perhaps indicating low barriers to entry. The testing of this hypothesis is for further study as it concerns 'performance developments within a country over time'.

It appears from the analysis that the presence and size of a competing cable network has a strong positive effect on broadband uptake and on data rates, while having a negative effect on prices. The analysis shows that access based competition (LLU) is important both in the presence and in the absence of infrastructure-based competition. The reason is that the LLU price has the most significant indirect influence on broadband performance. See the discussion on LLU wholesale pricing in the following section.

In the absence of cable as an alternative infrastructure to the PSTN, the only way to achieve competition in an economically viable way is access-based competition.

The analysis shows that at the aggregate, i.e. irrespective of the type of competition, performance is strongly but negatively related to the market share of the PSTN incumbent. As such the market share of the PSTN incumbent could also be used as a first approximation of the Structure Index, whereas the HHI* provides a more detailed specification. In the analysis of competition, the additional value of using structural equation modelling over simple regression models becomes very clear. SEM provides a more comprehensive explanation of how competition operates and how broadband performance should be explained.

Summary and inferences

The most prominent outcome of the statistical analysis is that the broadband market share of the PSTN incumbent is negatively related to performance, irrespective of the type of competition.

The analysis shows that access based competition (LLU) is important both in the presence and in the absence of infrastructure-based competition. Whilst in the presence of cable the market shares for access based competition are reduced, the LLU price has the most significant indirect influence on broadband performance. See the discussion on LLU wholesale pricing in the following section.

In the absence of cable as an alternative infrastructure to the PSTN, the only way to achieve competition in an economically viable way is access-based competition.

4.3 The effects of wholesale LLU prices on performance

The analysis shows that the LLU wholesale price (corrected for purchasing power parity) is the most important regulatory variable in explaining broadband performance. Considering the period of analysis (2008-2011) the role of LLU has become leading compared to alternative access products, such as resale and bitstream. See also Figures 14 and 15.[10]

From our analysis we can confirm the importance of wholesale price setting. The regulatory price for LLU (around an average of €10 per month)[11] has a contribution of minus 0.374 on the Performance Index. This means that reducing the LLU price by €1 increases the PI by up to 5 points, the combined effect of higher broadband penetration and data rates, and lower prices. Figure 10 indicates the relative impact on the Performance Index of differences in price for wholesale LLU. The calculation is formed by taking the average LLU price across the Member States represented and subtracting

[10] See footnote 9.

[11] Average total wholesale price for LLU (monthly rental fee and connection fee) (Source: European Commission Implementation Reports). Note that according to Cullen International, the LLU average monthly rental fee currently stands at 7.88 €/line/month (Source: Cullen International).

this from a country's LLU price. Next, the resulting 'difference' is multiplied by the effect of the LLU price on the PI (weight -0.374). Positive values indicate that a country has a below average LLU price.

Country	Impact on PI 2010	Country	Impact on PI 2010
AT	2	HU	0
BE	1	IE	1
BG	-3	IT	1
CH	1	LT	-1
CY	-1	LV	-2
CZ	-2	NL	2
DE	0	PL	0
DK	2	PT	0
EE	0	RO	-3
EL	0	SE	1
ES	1	SI	0
FI	0	SK	-1
FR	0	UK	1

Figure 10. Relative impact of LLU wholesale price (PPP corrected) on Performance Index outcome, 2010

The effect of LLU prices on market structure

Using the 2011 data, the wholesale price for LLU (full unbundling) appears to have no impact on the market share of LLU (see Figure 11). Indeed, if only countries are considered with a market share of LLU above 20% then the relationship seems to turn positive. We also tested the effect of the LLU price on the market share of LLU only (excluding shared). This provides the same results.

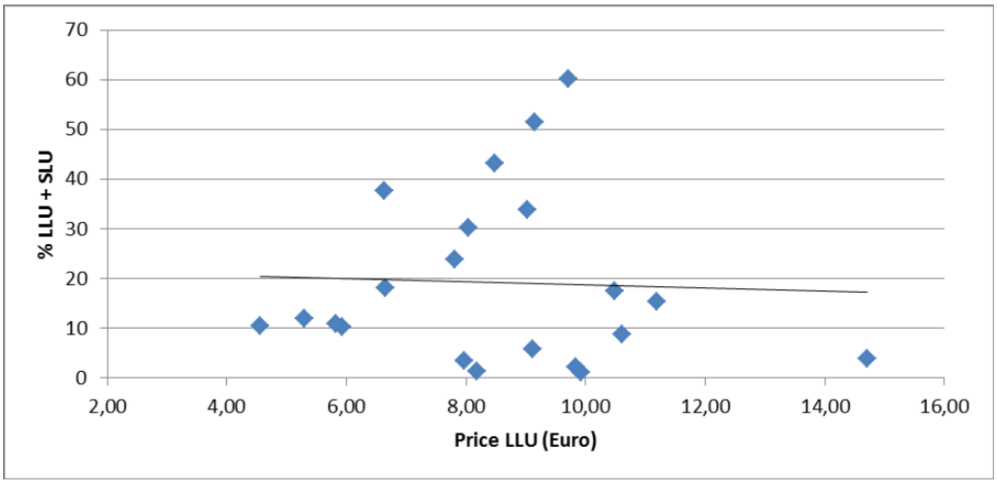

Figure 11. The effect of LLU wholesale price (full unbundling) on LLU market share (full and shared), 2011

At first sight there seems to be a puzzle: on the one hand we find that the price of LLU is important for competition and for performance, but it appears not to have an effect on the market share of LLU itself. According to Figure 12, however, a reduction in the price of LLU does lead to a reduction of the market share of the incumbent. With the aforementioned conclusion in mind that the market share of the incumbent is negatively related to performance, this explains why a lower LLU price leads to a higher broadband performance.

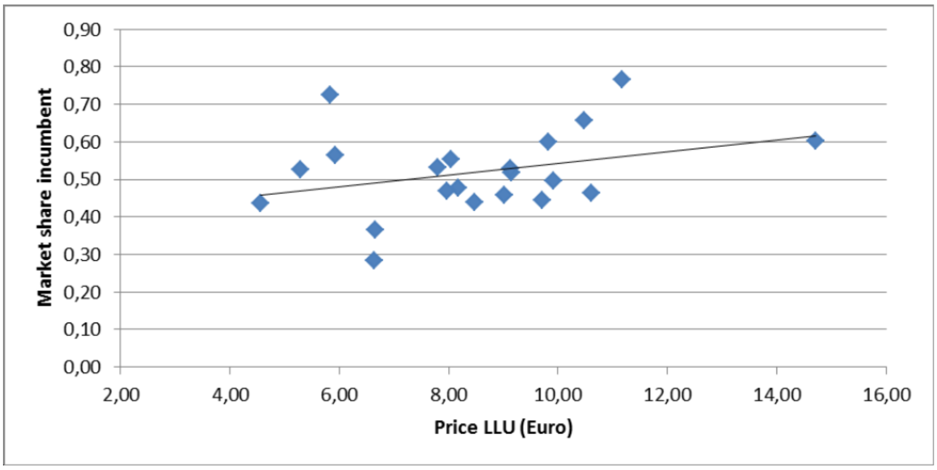

Figure 12. The effect of LLU wholesale price on the market share of the PSTN incumbent, 2011

To explain why the price of LLU affects the market share of the incumbent but not the market share of LLU, let us assume that the price of LLU is reduced. This allows LLU-based players to lower their retail prices. In turn, this puts competitive pressure on the competitors of these LLU players. However, not all competitors will necessarily follow the price reduction. The explanation for this phenomenon can be found in the field of consumer search and switching costs theory, which distinguishes between two types of consumers: 'captive' consumers and 'shoppers'.

In infrastructure markets, such as the fixed broadband market, a share of the consumer population is 'locked in' with their current supplier. These consumers typically face high switching and/or search costs, which makes it relatively unattractive for them to switch supplier. For instance switching costs occur when a consumer has a fixed contract and has to repay the discounts received when ending the contract early. Alternatively, search costs occur when consumers need to spend time and energy on finding out about potentially better offers. Maybe they are unaware of better offers existing in the market; maybe they are risk averse and have hence a low propensity to switch suppliers. These 'captive' consumers are therefore relatively less sensitive to prices. On the other hand there are consumers without or with low search and switching costs, typically called 'shoppers'. These can be consumers who are for example in the process of finding a new supplier or are simply always on the lookout for a bargain.

The suppliers need to balance the incentive to on the one hand exploit their captive consumers and on the other hand attract the shoppers. Incumbent firms with large market shares have a relatively high number of captive consumers and are therefore less inclined to compete for the shoppers.[12]

Therefore, the competitive pressure created by a reduction in LLU prices will trigger stronger reactions by competitors other than the incumbent. The result is that the incumbent loses some market share which will then be divided in some way across all the other competitive players. As the LLU-based players receive only a part of this market share, the relationship between LLU prices and the market share of LLU is less prevalent. This basically explains why market shares are relatively 'sticky' and why incumbents typically slowly lose their market share.

As the TCI research is extended to capture multiple years, this phenomenon across time may be further explored on a per country basis.

Nonetheless, the LLU market is important for competition even if this does not show in the cross country analysis of the market share of LLU. It serves as a 'catalyst' for competition, where LLU prices are important for LLU-based players to exert competitive pressure on the incumbent players, PSTN and cable alike. Hence, we can conclude that 'two is not enough for effective competition'. Ensuring low barriers to entry for new players, even if small scale, plays an important role in securing competitive outcomes.

Summary and inferences

The analysis shows that the LLU wholesale prices are the most important regulatory variable in explaining the difference in broadband performance across the EU.

In the presence of cable as an alternative infrastructure to the PSTN, which is largely a legacy phenomenon, infrastructure-based competition between the PSTN and the cable network operators combined with access-based competition through unbundling provides the best possible level of performance.

4.4 Wholesale prices and the 'ladder of investment' concept

The qualitative assessment of broadband markets has shown that the price level of wholesale access is also important for the type of access that is adopted by access seekers. Lower wholesale prices results in entrants 'climbing the ladder of investment' (Cave, 2004, 2006). The UK and France provide salient examples - see Figure 13, Figure 14 and Figure 15.[13]

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[12] For a more extensive discussion of consumer behaviour see the PhD research by Voogt (2012).

[13] See footnote 9.

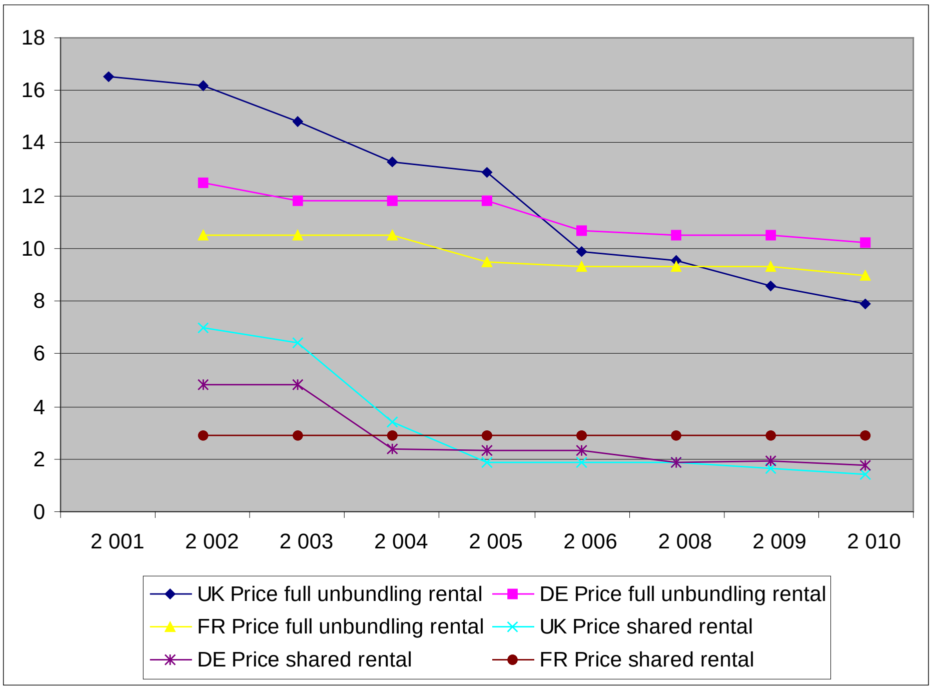

Figure 13. Comparison prices for unbundling in the UK, Germany and France, 2001-2010

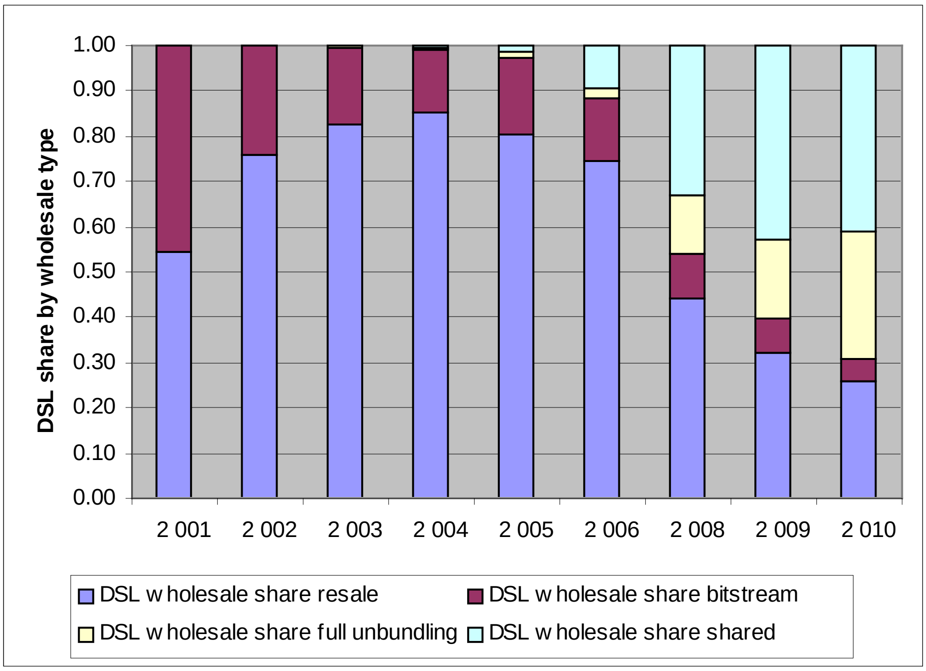

Figure 14. DSL share by wholesale type in the UK, 2001-2010

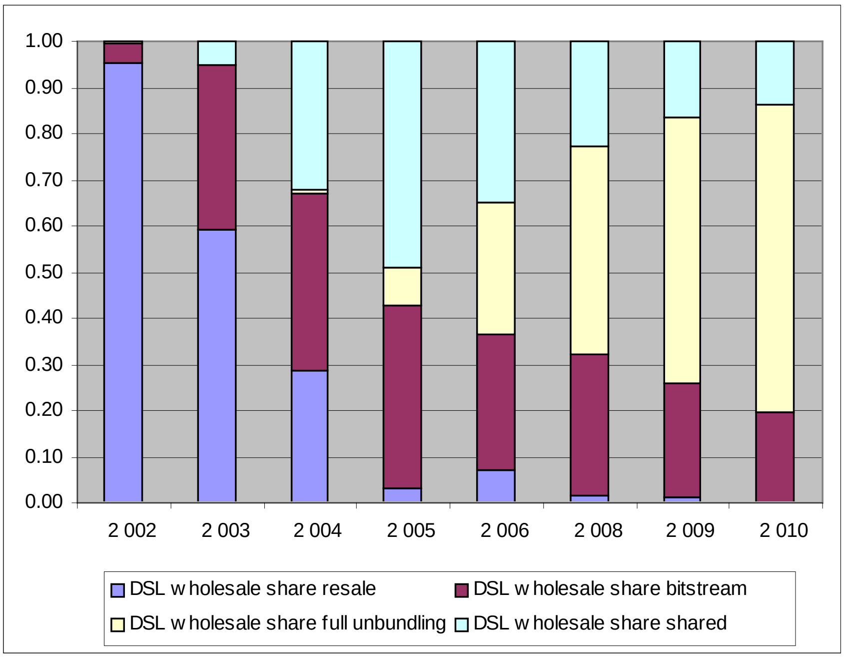

Figure 15. DSL share by wholesale type in France, 2002-2010

The figures illustrate the change in the composition of the access portfolio coinciding with the lowering of prices for the unbundling products.

As can be observed in the UK case, Oftel had originally set the unbundling prices relatively high compared to the two other countries. This may have been partly motivated by a desire to foster infrastructure competition. A major change in the LLU price was introduced by Ofcom in 2005, following a period in which take-up of LLU was seen to be low. The UK-case also shows that alternative operators do 'climb the ladder of investment' if the conditions are set right: from resale and bitstream to shared and full unbundling. In most cases the ladder has not extended to duplicating the final mile of the infrastructure – this could be because, especially in the presence of cable, such duplication may not be viable.[14]

However, where alternative operators have achieved a significant penetration and the conditions for fibre deployment are favourable, e.g. where cable is relatively weak and there is effective availability of ducts, alternative operators have reached the 'final rung of the ladder' by deploying fibre to the home (FttH). Examples are Free in France, where its fibre deployment triggered France Telecom/Orange, SFR and Bouygues to step up FttH deployment, FttH investments by alternative operators Jazztel, Orange &Vodafone in Spain, fibre to the cabinet (FttC) investments by Fastweb in Italy, as well as City carriers and local and regional alternative operators in Germany.

4.5 The relationship between competition and investment

We have seen that there is a positive relationship between competition (measured in terms of HHI* or incumbent market share) and performance. The analysis shows that the influence of investment per household on performance is also significant and

[14] See reference under footnote 8, where the conditions are explored under which alternative operators may reach the 'final rung of the ladder of investment'.

furthermore that GDP/capita has a strong positive impact on investment. This corroborates the notion that investments are required to provide network coverage and to provide (regular) network upgrades, enabling initial subscriptions and subsequent take up of higher data rates.

However, the link from market structure to firm conduct, i.e., from degree of competition to investment strategy, remains ambiguous. This may be explained by the lack of specificity of the investment data; only country aggregate data (fixed plus mobile, plant plus other investments) is available. Moreover, only in-period effects are considered across countries, rather than temporal effects within a country.

Earlier analysis of investment in the telecommunications sector suggests that also a strong underlying cyclical pattern caused by the implementation of successive generations of technology is present, which may make the association with other factors harder to measure. See Figure 16 (Lemstra, 2006).

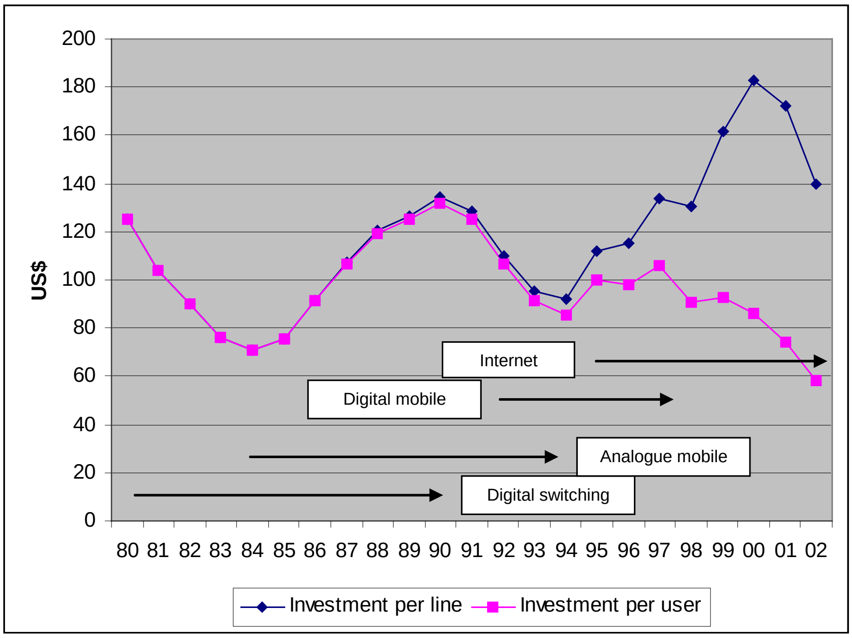

Figure 16. Investments per line and user, Western European sample, 1980-2002

Another hypothesis might be that different factors pull in different directions. For example greater competition might lead both to a higher degree of infrastructure duplication (in the core network) and to a lesser extent in the access network. However competition may also provide constraints that increase the efficiency of investments.

Summary and inferences

The TCI finds a positive relationship between investments (as a conduct indicator) and performance. In fact investments have the strongest influence on the PI of any of the indicator. As noted in Section 3.2, the main driver of investments is found to be GDP per capita, suggesting that factors exogenous to the telecommunications sector play a substantial role.

The TCI model does not find any significant relationship between competition and investment. This could be due to the lack of granular data. Alternatively, it could result from the potential that competition may have mixed effects on investment levels, both boosting network duplication (which should increase overall investment), whilst promoting ‘efficiency’ (which should reduce overall, potentially unsustainable investment levels).

4.6 The relationship between urbanization and performance

The analysis identified from the list of ‘basic conditions of supply’, the variable ‘degree of urbanization’, as a proxy for differences in the cost structure between countries as being statistically significant. High urbanization rates are consistent with a higher penetration of cable and higher use of local loop unbundling. As such urbanization improves competition, which is indeed reflected in the model as it has a negative effect on the HHI*. The effect of the degree of urbanization on performance, through the CI, is significant with a weight of 0.116.

Summary and inferences

With the weights for GDP/cap and the degree of urbanization being significant but outside the scope of telecommunications policy and regulation, the performance index is corrected for these factors with the results being reflected in Figure 8. The data shows that the relatively high Performance Index of the richer countries can partly be explained by their relatively higher income. Correcting for these two exogenous factors bring the countries closer together.

5 From ‘Basic Broadband’ to ‘Next Generation Broadband’

In our current analysis the focus has been on ‘basic broadband’. The explanatory and confirmatory factor analysis has shown that the ‘next generation broadband’ attributes are insignificant in the presence of ‘basic broadband’ attributes in explaining broadband performance across the EU. This is largely due to the relatively low uptake of NGA to date, hence the use of the 10 Mbit/s criterion instead of the 30 Mbit/s one, in the path model.

Nonetheless, initial steps in the analysis of ‘next generation broadband’ have been performed so as to explore emerging relationships. While no conclusions can be drawn on the strength of the relationships, an indication can be provided on the direction of the anticipated relationships.

For the initial analysis data from 2011 is used. Furthermore, two different samples of countries are used. The largest sample consists of the EU-27 minus Malta and Latvia, due to missing relevant data. As the ‘basic broadband’ analysis already indicated, certain countries are outliers, in that they typically have a substantial NGA coverage compared to a relatively low broadband performance overall. These countries may have achieved greater NGA performance due to a ‘grassroots’ deployment of fibre enabled by for instance more relaxed urban planning controls, which does not apply to other countries under consideration. Hence, the smaller sample excludes these countries, i.e., Cyprus, Bulgaria, Romania, Slovakia and Lithuania. This results in a set of 20 countries in this sample.

NGA is defined as the sum of VDSL-2, DOCSIS-3 and FttP (Fibre to the Premise).

As for ‘basic broadband’, no significant relationships between investment and NGA deployment are found.

5.1 The relationship between NGA and performance

The relationship between NGA coverage and broadband performance in the larger sample shows a flat relationship in the scatter plot, i.e., no linkage between NGA coverage and broadband performance is apparent. For the smaller sample (excluding some new member states which have benefited from ‘grassroots’ FttH deployment) this relationship turns positive. See Figure 17. The latter plot would corroborate the logic that uptake of basic broadband and the proportion of broadband taken at data rates of 10Mbit/s or above – which are key attributes in the performance construct – may contribute to increasing demand for broadband at higher data rates. However, this causal inference remains to be tested with more complete data on NGA developments in future years, allowing for a proper regression analysis, including testing for statistical significance.

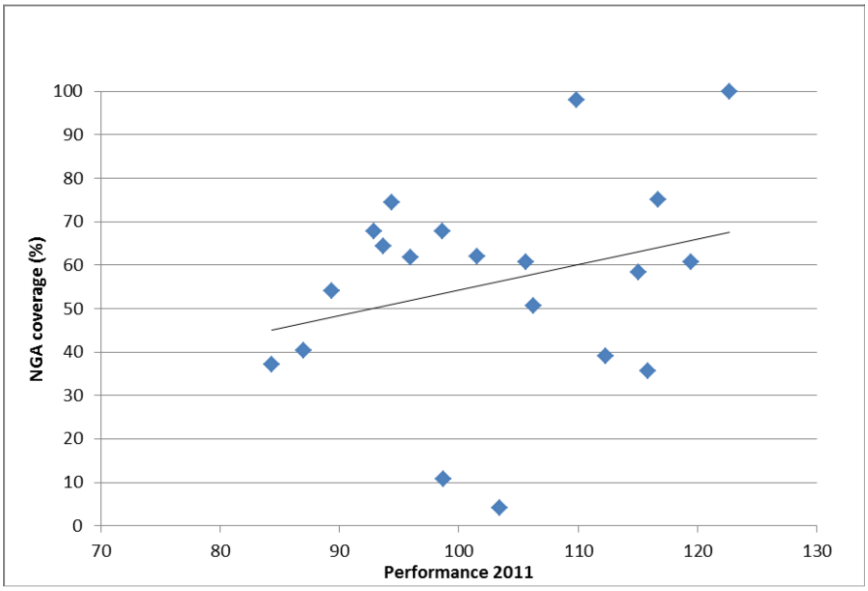

Figure 17. Relationship between NGA coverage and performance, smaller sample, 2011

The performance index also includes a measure of prices for broadband. A potential linkage that is relevant to be analysed when more data on NGA developments becomes available is how retail prices are linked to NGA roll-out.

Summary and inferences

Increased broadband performance is positively linked with NGA coverage suggesting a dynamic effect whereby increased uptake of basic broadband supports investment in next generation broadband.

5.2 NGA coverage and competition for NGA

The analysis of NGA coverage suggests a strong relationship with DOCSIS-3-based cable coverage, for both the large and the smaller sample of countries. See Figure 18 reflecting the scatter plot for the larger sample of countries.

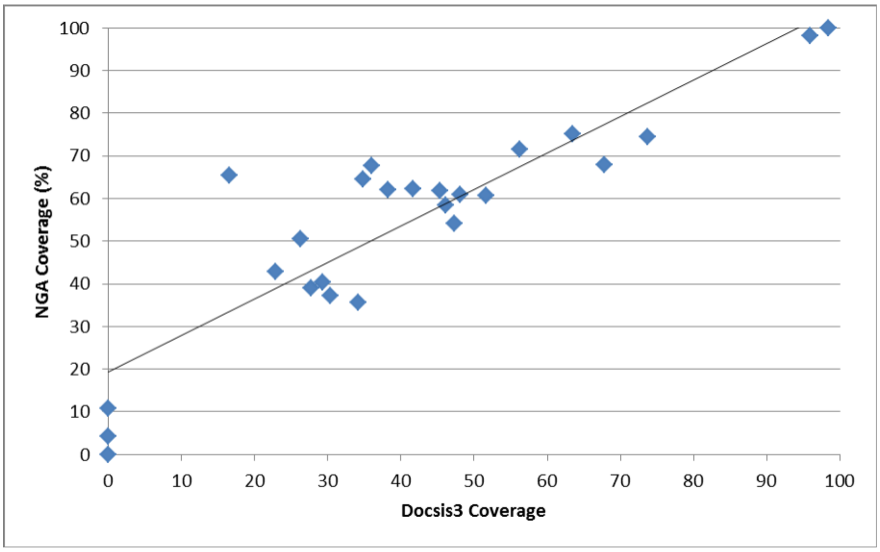

Figure 18. NGA coverage in relation to DOCSIS-3 coverage, large sample, 2011

The DOCSIS-3 coverage is quite close to the NGA coverage in absolute numbers. The average for our large sample is 55% of households covered by NGA and 41% covered with DOCSIS-3. This is the average across the sample, including the countries which do not have cable coverage at all. This implies that in 2011, 75% of the NGA coverage is secured by cable alone. However, from this fact alone one should not conclude that it is necessary to focus only on cable when considering NGA. The effect of the presence of cable (DOCSIS-3) on the roll out of other NGA technologies also needs to be analysed.[15]

As a first step in the analysis, Figure 19 shows the relationship between NGA coverage and VDSL+FttP coverage. Similarly to the relationship of NGA coverage with DOCSIS-3 coverage, the plots suggest a positive relationship. However, the slope for the DOCSIS-3 coverage is steeper, which implies that this technology is the most important explanatory factor for the coverage of NGA.

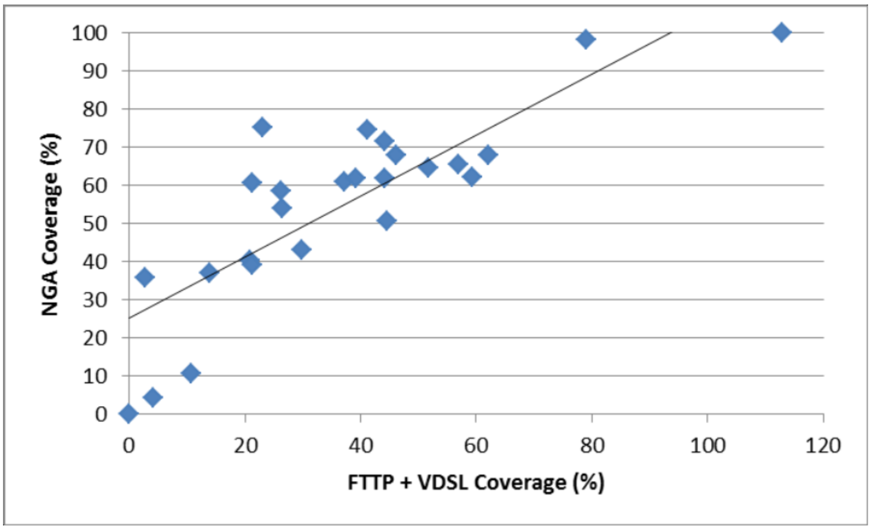

Figure 19. NGA coverage in relation to FttP+VDSL coverage, large sample, 2011

In the next step of the analysis, the relationship between the different NGA technologies is explored. In Figure 20 the relationship between DOCSIS-3 coverage (horizontal axis) and the combination of VDSL and FttP coverage is reflected for the larger sample of countries. There appears to be a rather strong positive relationship. This would imply that DOCSIS-3 based cable coverage has a positive indirect effect on the roll out of other NGA technologies, such as VDSL and FttH. This could imply that DOCSIS 3 stimulates NGA roll-out by other players.

As over time new data will become available on NGA developments the hypothesized relationship may be tested for statistical significance, and subsequently on its direction and strength.

[15] Note that overlap between different types of technologies can occur.

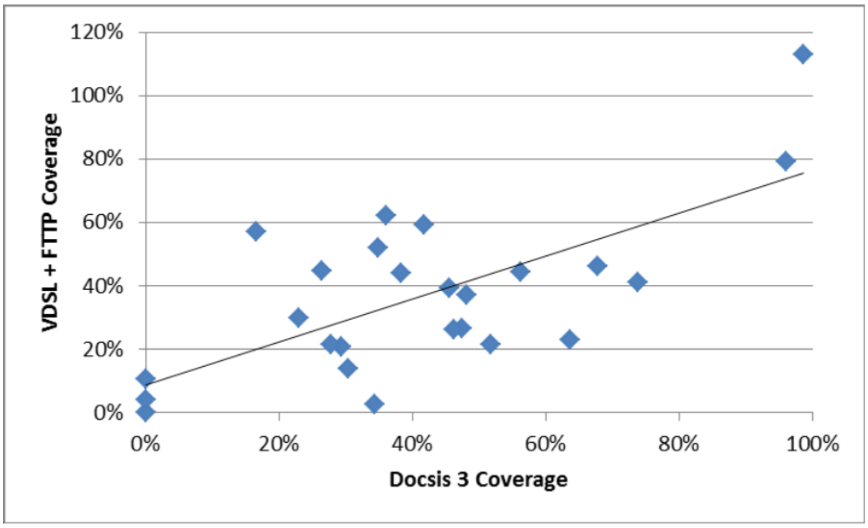

Figure 20. Relationship between DOCSIS-3 coverage and VDSL+FttH coverage, large sample, 2011

Summary and inferences

NGA coverage is determined by a combination of DOCSIS-3 coverage, VDSL-2 coverage and FttP coverage. In 2011, NGA coverage is foremost determined by DOCSIS-3 coverage: 75% of the NGA coverage is secured by cable alone.

There appears to be a strong relationship between DOCSIS-3 roll-out and the roll-out of other NGA technologies, suggesting that DOCSIS-3 may trigger a reaction stimulating others to invest. However, the strength of this relationship needs to be examined as further data becomes available.

5.3 Relationship between 'basic broadband' competition and NGA coverage

To explore the relationship between intensity of broadband competition and 'next generation broadband' development, the effect of the technology platform HHI* (the concentration metric) on the coverage and uptake of NGA is analyzed. Note that the HHI* captures the market share of competitive platforms, distinguishing the incumbent, cable and access-based competitors and that the HHI* is a negative index, hence, a higher concentration ratio implies a lower level of competition.

As the scatter plot in Figure 21 shows, the effect of broadband competition (measured through the HHI*) on NGA coverage appears to be rather small, but positive. Although the spread in observations seems large, the relationship holds for both the larger sample (as shown) and the smaller sample set of countries. This leads to the formulation of the hypothesis that more competition in 'basic broadband', including infrastructure-based and access-based competition, leads to an increase in the coverage of 'next generation broadband'. This hypothesis can only be tested once more data in NGA developments becomes available in the near future.[16]

[16] The platform HHI does include the market share of NGA technologies, so this inference only holds as long as the NGA share is relatively small, which is the case in 2011.

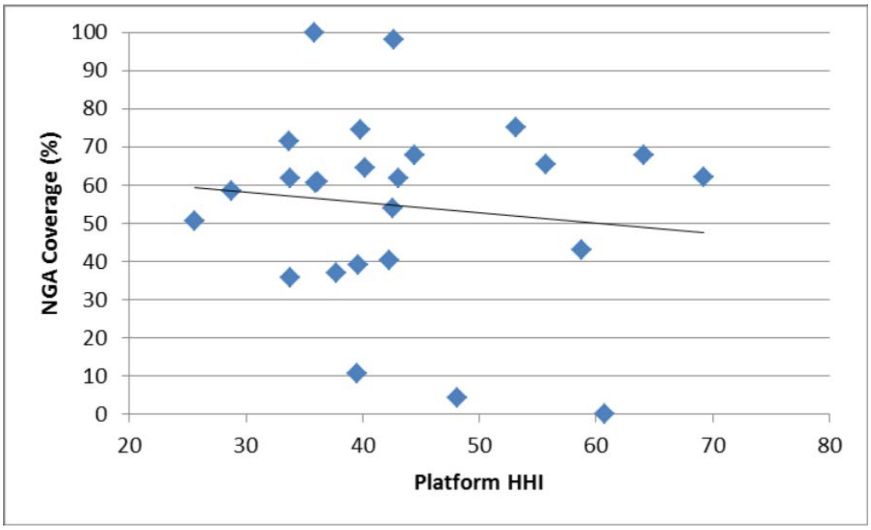

Figure 21. Relationship between platform HHI and NGA coverage, large sample, 2011

Summary and inferences

A hypothesis is formulated that intense competition in 'basic broadband', through infrastructure-based and access-based competition, contributes to an increase in the coverage of 'next generation broadband' to be tested when more data on NGA developments becomes available.

5.4 Relationship between 'basic broadband' competition and NGA uptake

Figure 22 shows, on the basis of a scatter plot, the relationship between platform HHI* and NGA uptake for the smaller set of countries. This set (excluding countries with high NGA penetration and low overall performance) shows a small negative effect, implying that an increase in the level of competition also increases the uptake of NGA.

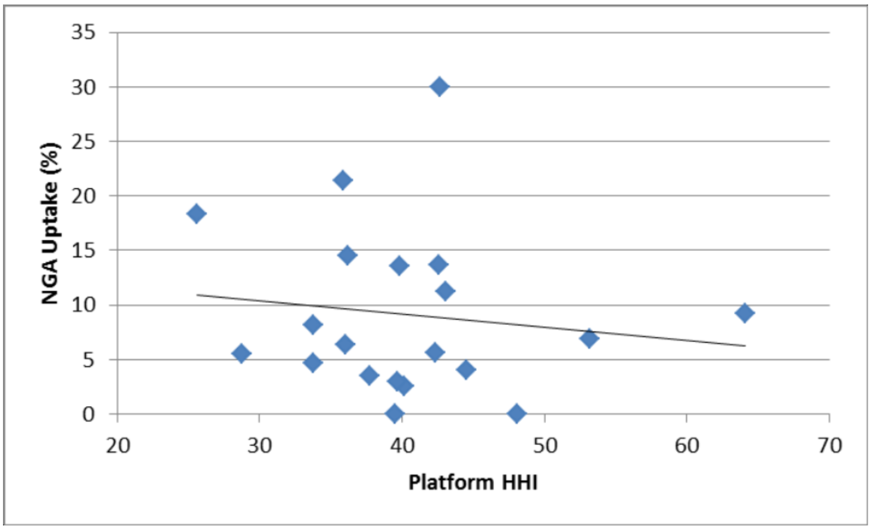

Figure 22. Relationship between platform HHI and NGA uptake, smaller sample, 2011

Summary and inferences

The hypothesis to be tested once more data becomes available is that an increase in the level of competition in basic broadband will increase the uptake of NGA.

5.5 The relationship between 'basic broadband' competition and data rates

The relationship between the platform HHI* and the uptake of broadband with data rates above 10 Mbit/s appears to be positive for both sample sets. Figure 23 shows the case for the larger sample. This suggests that a hypothesis is warranted that higher intensity of competition drives the uptake of higher data rates to be tested when more data on NGA developments becomes available.

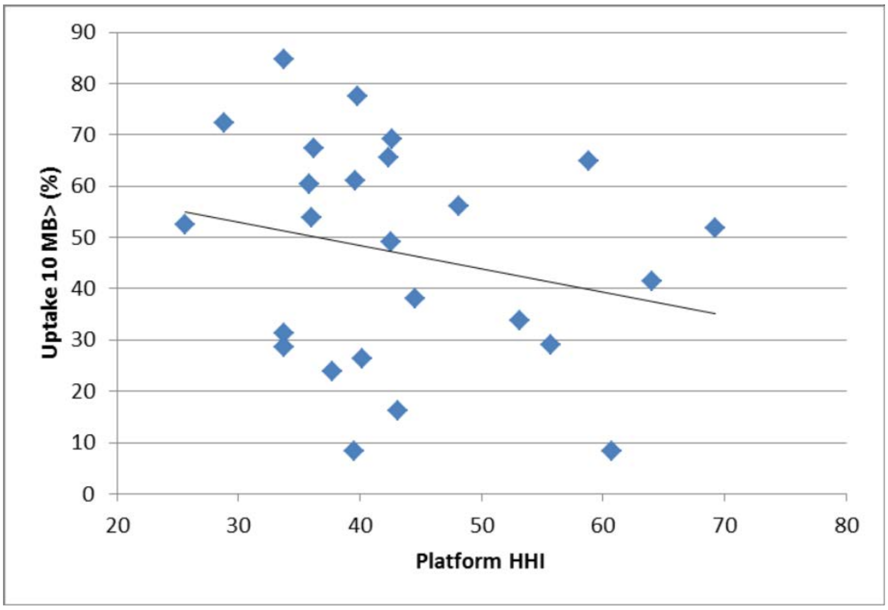

Figure 23. Relationship between platform HHI and uptake of data rates above 10 Mbit/s, larger sample, 2011

Summary and inferences

The hypothesis to be tested once more data becomes available is that a higher intensity of competition will drive the uptake of higher data rates.

6 Topics for future research

The first round of research has yielded a parsimonious path model for fixed broadband, which appears to be robust over the years 2008-2011. The research has also revealed areas where the data set can be improved and the model might be extended.

In particular, as the deployment of NGA progresses, more data will become available such that the model may be enhanced to reflect the progression towards higher data rates. Hence, also the high end targets of the Digital Agenda may be captured. Moreover, the hypotheses that have been formulated on NGA development can be tested.

As data over a longer period becomes available this will also allow for temporal research aimed at explaining developments over time on a per country basis.

Acknowledgements

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Annex A – Country codes

AT	Austria	ES	Spain	MT	Malta
BE	Belgium	FI	Finland	NL	Netherlands
BG	Bulgaria	FR	France	PT	Portugal
CH	Switzerland	GR	Greece	PL	Poland
CY	Cyprus	HU	Hungary	RO	Romania
CZ	Czech Republic	IE	Ireland	SE	Sweden
DE	Germany	IT	Italy	SI	Slovenia
DK	Denmark	LT	Lithuania	SK	Slovak Republic
EE	Estonia	LU	Luxembourg	UK	United Kingdom
EL	Greece	LV	Latvia		

Annex B – Underlying data Performance Index 2009-2011

	2009					2010					2011				
Country	Uptake	Data rate	Price	Investment	Concentration	Uptake	Data rate	Price	Investment	Concentration	Uptake	Data rate	Price	Investment	Concentration
AT	54	28	25	109	37	58	38	30	109	39	60	26	31	109	40
BE	70	41	20	214	40	75	57	19	214	43	80	69	20	214	43
BG	34	61	28	39	46	40	74	28	39	36	45	85	28	39	34
CY	70	0	37	351	68	74	5	36	351	62	88	8	21	351	61
CZ	42	18	48	60	43	48	28	38	60	45	53	66	41	60	42
DE	65	25	34	125	34	68	30	33	125	35	71	31	34	125	34
DK	82	35	15	346	39	85	48	24	346	37	82	67	25	346	36
EE	63	9	35	97	47	68	10	27	97	46	69	16	27	97	43
EL	52	5	23	223	48	61	54	19	223	48	69	56	20	223	48
ES	62	19	30	200	40	67	34	28	200	37	70	54	29	200	36
FI	64	16	26	206	42	64	33	25	206	48	66	41	26	206	64
FR	77	45	28	211	36	82	55	25	211	38	87	61	28	211	40
HU	47	31	36	29	37	54	41	27	29	41	60	49	30	29	43
IE	75	9	18	262	40	77	13	18	262	38	81	29	18	262	34
IT	52	8	23	195	42	56	9	23	195	40	58	8	24	195	40
LT	42	26	26	53	69	45	42	19	53	69	48	52	19	53	69
LU	82	8	18	396	52	81	27	17	396	56	84	34	17	396	53
NL	90	47	22	300	34	92	57	21	300	37	94	60	22	300	36
PL	40	4	18	10	41	44	12	27	10	39	47	24	30	10	38
PT	52	61	29	71	34	58	30	29	71	39	63	78	32	71	40
RO	39	52	12	10	53	42	60	9	10	56	45	65	16	10	59
SE	66	43	21	137	27	67	48	21	137	24	66	52	23	137	26
SI	68	18	37	108	31	69	26	35	108	30	78	38	38	108	45
SK	32	22	41	67	63	37	25	40	67	59	40	29	41	67	56
UK	73	25	16	184	26	75	45	18	184	28	80	72	15	184	29
AV	**60**	**26**	**27**	**160**	**43**	**64**	**36**	**25**	**160**	**43**	**67**	**47**	**26**	**160**	**43**

Uptake = % of households with a broadband connection (source: Cocom)

Data rate = % broadband connections with more than 10 Mbit/s download capacity (source: Cocom/European Commission)

Price = average monthly fixed revenu per bb connection, Euro adj. ppp (source: ITU)

Investments = average annual investments per household, Euro (source: ITU)

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