

Haucap, Justus; Heimeshoff, Ulrich; Lange, Mirjam R. J.

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The Impact of Tariff Diversity on Broadband Diffusion - An Empirical Analysis

Justus Haucap* Ulrich Heimeshoff* Mirjam R.J. Lange*

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Abstract

This paper provides an empirical analysis how tariff diversity affects broadband uptake, utilizing a new data set with 1497 fixed-line and 2158 mobile broadband tariffs from 91 countries across the globe. An instrumental variable approach is applied to estimate the demand for fixed broadband internet access, controlling for various industry and socio-economic factors. The empirical results indicate that, first, in addition to lower prices and higher income, more tariff diversity additionally increases broadband penetration. Secondly, inter-platform competition and mobile broadband prices are not found to have a significant effect on fixed-line broadband penetration. This suggests that low prices, higher incomes and the diversity of broadband offerings are more important drivers of fixed broadband adoption than competition between various technologies (cable networks, fixed-line telephone networks, mobile networks).

JEL Classification numbers: L86, L96.

Keywords: Broadband prices; Tariff diversity; Broadband demand; Broadband penetration, Broadband uptake; Price discrimination; Inter-platform competition

*Heinrich-Heine-University of Düsseldorf, Düsseldorf Institute for Competition Economics (DICE), Universitätsstr. 1, 40225 Düsseldorf, Germany.
E-mail: haucap@dice.hhu.de, heimeshoff@dice.hhu.de, lange@dice.hhu.de.

1 Introduction

Around the globe, policy makers see broadband penetration as a key driver for economic growth (see, e.g. OECD 2008). Broadband directly or indirectly spurs innovation, productivity, and, thereby, a country's national competitiveness. Therefore, the number of high-speed Internet connections has become an important indicator for a country's growth potential (e.g. Crandall, Hahn & Tardiff 2002, OECD 2003, ITU 2003, ITU 2006). A timely deployment and uptake of broadband infrastructure has, therefore, become a major policy objective for many governments.

In fact, the perspective that broadband infrastructure deployment has positive effects on growth is also supported by empirical evidence. Ever since the by now seminal study of Röller & Waverman (2001) found that telecommunications infrastructure is one of the key drivers of economic growth, many other studies have come to very similar findings, demonstrating the robustness of Röller & Waverman's empirical findings across time as well as across countries and regions. Koutroumpis (2009), for example, has analyzed the impact of broadband penetration on countries' GDP and found that a 10% increase in broadband coverage results in an increased growth rate of 0.25% for OECD member states. Qiang, Rossotto & Kimura (2009) have suggested that the effect of increased broadband penetration is even larger: According to this study, each additional percentage point of broadband penetration results in a 0.121% increase in the GDP growth rate in high-income countries and even 0.138% in low- and middle-income countries. More recently, the prominent study by Czernich, Falck, Kretschmer & Woessmann (2011) has found that a 10% increase in broadband penetration has even raised annual per capita growth by 0.9-1.5% between 1996-2007 in 25 OECD member states. Further studies that demonstrate how broadband penetration positively affects economic growth include Pradhan, Bele & Pandey (2013), Sassi & Goaid (2013), Jung, Na & Yoon (2013), Chavula (2013), Lee, Levendis & Gutierrez (2012), Gruber & Koutroumpis (2011), Thompson & Garbacz (2011), Shiu & Lam (2008), and Lam & Shiu (2010). The empirical literature on the impact of broadband on individual firms' productivity, which induces the macroeconomic growth effects in the end, has been nicely summarized in more detail by Cardona, Kretschmer & Strobel (2013).

As a natural consequence, broadband policy now has a prominent role on many government agendas (see, e.g., ITU & UNESCO 2013). In Europe, Asia and North America substantial efforts have been undertaken to foster the diffusion of broadband infrastructure, access, and services. In Europe, for example, various action plans that aim at making the European Union the "most competitive and dynamic

knowledge based economy” (European Council 2000) have been launched over the last decade. More recently, the US government’s National Broadband Plan and the European Commission’s Digital Agenda for Europe focus on extending internet connectivity and on reducing prices for broadband access. Given that Europe is still lagging behind its main Asian competitors as well as the US (see, e.g., Briglauer & Gugler 2013), the European Commission’s “Europe 2020 Strategy” has outlined a number of objectives to ensure that “by 2020, (i) all Europeans have access to much higher internet speeds of above 30 Mbps and [that] (ii) 50% or more of European households subscribe to internet connections above 100 Mbps” (European Commission 2010, p. 20).

Given these ambitious objectives, there has been considerable interest in understanding the key factors that drive broadband diffusion. A growing body of empirical literature, which will be reviewed in more detail in section 2 of this paper, has been analyzing what affects broadband deployment and uptake either at a single-country or at a cross-country level, in order to single out the factors that drive broadband penetration. In short, most papers have focused on (a) broadband price levels, (b) income, (c) socio-demographic characteristics, (d) Government policy and regulation, and (e) the degree of inter- and intra-platform competition. This paper will also take these factors into account, but in addition to previous studies the present analysis also accounts for the degree of tariff *diversity*. To the authors’ knowledge the focus on tariff diversity is new and, hence, one of the main novelties of this paper. While it is rather clear that price *levels* should have an impact on broadband uptake, it is, however, for a theoretical perspective less clear *ex ante* how tariff diversity should affect broadband penetration. On the one hand, classical industrial economics theory suggests that price discrimination in final consumer markets should lead to an expansion of output (i.e., increased broadband penetration in the case at hand), as it allows suppliers to serve low-value customers without lowering the price for high-value customers at the same time. On the other hand, however, accounting for more recent theories of boundedly rational consumer behavior the prediction becomes less clear. As e.g. Spiegler (2006) has argued, consumers may become confused over “too much variety” or “too many tariffs”. In fact, there has been a burgeoning literature which demonstrates that consumer decisions are prone to mistakes in telecommunications markets (see, e.g., Bolle & Heimel 2005, Lambrecht & Skiera 2006, Haucap & Heimeshoff 2011). Based on these findings, Eliaz & Spiegler (2006), Brown, Hossain & Morgan (2010), Piccione & Spiegler (2012), and Herweg & Mierendorff (2013) have developed models which suggest that firms may sometimes deliberately choose to obfuscate consumers in order to increase their

profits. As a consequence, consumers may become frustrated and more reluctant to sign a contract. In fact, the success of (simple) flat-rate tariffs in telecommunications markets may suggest that simple tariffs may be more helpful in fostering penetration than more diverse and complicated offerings. From a theoretical perspective it is, therefore, not entirely clear how tariff diversity affects broadband uptake: While classical industrial economic theory would suggest a positive relationship between tariff diversity (as a measure for price discrimination) and broadband uptake, the more recently advanced behavioral economics view may suggest a negative one (seeing tariff diversity as a measure for customer obfuscation strategies).

The purpose of this paper is to provide an empirical assessment for how tariff diversity influences broadband uptake, while accounting for other factors that affect broadband penetration such as price *levels*, income, demographic factors, and public policy. The analysis accounts for two main dimensions of fixed broadband offerings, namely speed and price. To make price levels across different speed levels comparable tariffs are standardized by the offered download speed so that tariffs are expressed in the price per Megabit per second (Mbps). In addition, other tariff characteristics may further differentiate the service and affect “quality” such as the underlying technology, network stability, or service offers. The characteristics are unfortunately not directly observable or quantifiable for the authors, even though they may potentially affect consumers’ willingness to pay and, therefore, equilibrium prices.

The empirical analysis is based on a newly available data set that includes around 1500 broadband-only-offers (without any further bundled services) from 91 countries for the third quarter of 2012. Hence, the second major novelty of this paper is, apart from its research focus on tariff *variety*, the use of an entirely new data set. For the econometric analysis, an instrumental variable approach is used to estimate the demand for fixed broadband Internet access, controlling for industry-specific and socio-economic effects. As expected, the empirical analysis reveals that lower prices and higher income foster broadband uptake. In addition, an increase in tariff diversity provides a further impetus for broadband penetration, supporting the classical perspective that price discrimination induces output expansion. Beyond these effects, neither inter-platform competition (cable vs. telephone networks) nor mobile broadband prices have any direct additional influence on broadband penetration.

The remainder of the paper is now organized as follows: Section 2 reviews the relevant academic literature, before section 3 introduces the underlying data, the estimation strategy employed and the empirical results. Section 4 finally discusses the findings and concludes.

2 Literature Review

There is a steadily growing body of literature on drivers and impacts of broadband penetration. Two approaches have been used to address the issue: Firstly, a mostly descriptive approach which aims at identifying drivers for broadband uptake through a largely qualitative analysis (OECD 2001, Wu 2004) and, secondly, empirical analyses based on econometric models that estimate broadband demand, thereby explaining observed differences. The number of these empirical papers on broadband deployment, uptake, and policy has grown quite noticeably most recently. The studies have examined various economic, demographic, geographic, and policy variables which may plausibly explain cross-country differences in broadband penetration (see, e.g., Kim, Bauer & Wildman 2003, Garcia-Murillo 2005, Distaso, Lupi & Manenti 2006, Cava-Ferreruela & Alabau-Muñoz 2006, Lee & Brown 2008, Trkman, Blazic & Turk 2008, Lee, Marcu & Lee 2011, Galperin & Ruzzier 2013, Lin & Wu 2013). The key findings of these studies will be briefly discussed below.

Price: Several studies have stressed that the broadband price *level* is a significant factor in determining broadband demand in any given country. Among these studies are, for example, Distaso et al. (2006), Cava-Ferreruela & Alabau-Muñoz (2006), Denni & Gruber (2007), Wallsten & Hausladen (2009), Bouckaert, van Dijk & Verboven (2010), Lee et al. (2011), and Briglauer (2014) to name just a few. To provide an example, Galperin & Ruzzier (2013) have recently shown in their study of broadband in Latin America and the Caribbean (LAC) that broadband demand may actually be quite elastic. According to Galperin & Ruzzier an average price reduction of 10% results in an increase in broadband demand of almost 22% in the penetration rate in LAC, equivalent to almost 8.5 million additional broadband connections. In addition, Lin & Wu (2013) have shown in their analysis of broadband adoption in the OECD from from 1997 to 2009 that broadband price levels have been especially important for late adopters. Overall, the empirical evidence that low price levels foster broadband penetration is overwhelming.

Income: Nearly all of the studies referred to above also include income levels in their analysis and nearly all of them find, somewhat unsurprisingly, that income (GDP per capita) is a driving factor for fixed broadband demand. For example, Gruber & Koutroumpis (2013) have clearly found a positive and significant impact of income on broadband demand in both their panel data analysis of 30 OECD countries from 1999 to 2003 as well as in their panel data analysis of 167 countries from 2000 to 2010, respectively. In a more detailed study of the broadband diffusion process, Lin & Wu (2013) have shown that disposable household income is

especially of importance for broadband adoption in the early adoption phase. In general, income has been identified as an important factor for broadband adoption across OECD countries.

Competition: Competition for broadband customers can basically take two forms: (i) service-based competition over the same infrastructure through open access provisions at various network layers, referred to as intra-platform competition, and (ii) facility-based competition between different technological platforms that can be used to provide broadband access, referred to as inter-platform competition. Generally speaking, the vast majority of studies has found that especially inter-platform competition has positive effects on broadband diffusion (see, e.g., Cava-Ferreruela & Alabau-Muñoz 2006, Distaso et al. 2006, Höffler 2007, Denni & Gruber 2007, Bouckaert et al. 2010, Nardotto, Valletti & Verboven 2013). Quite recent studies have, however, also produced different findings: Briglauer, Ecker & Gugler (2013) as well as Briglauer (2014) have found a non-linear relationship between inter-network competition and broadband diffusion, while both Calzada & Martínez (2013) and Gruber & Koutroumpis (2013) have found no evidence for inter-platform competition accelerating broadband diffusion. With respect to intra-platform competition, the results differ even more: While Lee et al. (2011) have found unbundling and service-based competition to foster broadband uptake, Denni & Gruber (2007), Distaso et al. (2006), Cava-Ferreruela & Alabau-Muñoz (2006), and Höffler (2007) found only small or insignificant effects. Moreover, Wallsten & Hausladen (2009), Bouckaert et al. (2010), and Briglauer et al. (2013) have even found that facilitating intra-network competition through access regulation negatively affects broadband penetration as it reduces incentives for broadband investment. Hence, the overall findings with respect to intra-platform competition are completely mixed, while inter-platform competition appears, by and large, to spur broadband penetration if a significant effect can be found.

In addition to these three factors (price levels, income, competition) a number of **other variables** have been examined in the literature such as demographic factors (e.g., age, education, and population density) or network characteristics such as the broadband speed available. Lee & Brown (2008), for example, have found that broadband speed and bandwidth (measured as bits per inhabitant), contribute to broadband adoption in OECD countries.¹ Lin & Wu (2013) find that, apart from price levels and income, content and education are the main driving forces in the first (early adoption) stage. Trkman et al. (2008) suggest that education and popu-

¹Lee & Brown (2008) use two different data sets provided by the OECD and the ITU covering different time spans, from 1999-2006 and 2002-2006, respectively.

lation density are influential demographic factors of fixed broadband deployment in European Union countries. Cava-Ferreruela & Alabau-Muñoz (2006) argue that the “predisposition” to use new technologies appears to be a key driver for broadband supply and demand.

All of these studies have significantly contributed to a deeper understanding of the determinants of fixed broadband adoption. However, to the best of the authors’ knowledge not a single study has accounted for the extent of price differentiation so far. This study now contributes to the existing literature by adding tariff diversity as another potential factor to determine broadband demand.

3 Empirical Analysis

3.1 Data and Econometric Specification

The empirical analysis is based on a newly available data set that includes around 1500 broadband-only-offers (without any further bundled services)² from 91 countries for the third quarter of 2012. The data on broadband tariffs is provided by Google and was gathered by visiting operator websites in the course of July 2012.³ All tariffs are aggregated on a country-level and prices are converted from local currency into US dollars, using purchasing power parity (PPP) exchange rates, which are taken from World Bank for the year 2011.⁴ Data for social, economic, and demographic indicators was gained from World Bank as well as ITU World Telecommunication Indicators Database. Out of 91 included countries 26 are OECD members and 65 are OECD non-member states.⁵

3.1.1 Prices

Price levels

According to economic theory of a downward sloping demand curve (for ordinary goods and services), a negative impact of price on broadband diffusion is expected. The price variable is measured by a tariff’s monthly charge. Since fixed-line broadband tariffs are differentiated with respect to speed and price, we standardize them

²Bundled services could be voice telephony, pay TV, mobile services and so on. If a broadband-only offer was not available, tariff offers of broadband combined with voice telephony were captured. Triple play offers (broadband+voice+TV) were excluded entirely.

³The full data set is available under: <http://policybythenumbers.blogspot.de/2012/08/international-broadband-pricing-study.html>

⁴For Iran, Lybia, Syria and Taiwan no data was available for 2011, therefore the latest information from 2009 was implemented.

⁵Table 4 states all included countries in this study.

by their advertised download speed, thus a fixed-line broadband tariff's price is measured by monthly charge (in US\$ PPP) per Mbps. The prices are aggregated on a country-level by calculating the average of all tariffs offered in a country. To reduce the impact of outliers the upper and lower two percent of all offers are excluded. As

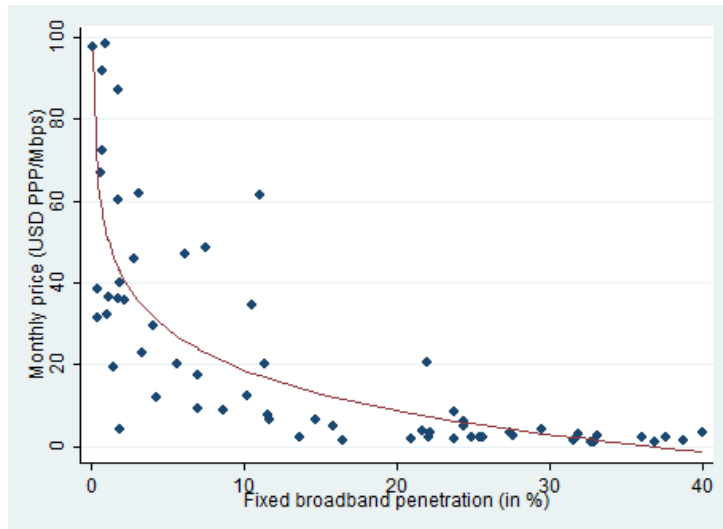


Figure 1: Relationship between price and fixed broadband subscribers

illustrated by Figure 1 there is a negative relationship between price and diffusion rate. Hence, countries with higher broadband coverage are characterized by lower prices, maybe as suggested by ITU (2003) as a result of flourishing competition and innovative pricing schemes to attract a wide variety of customers.

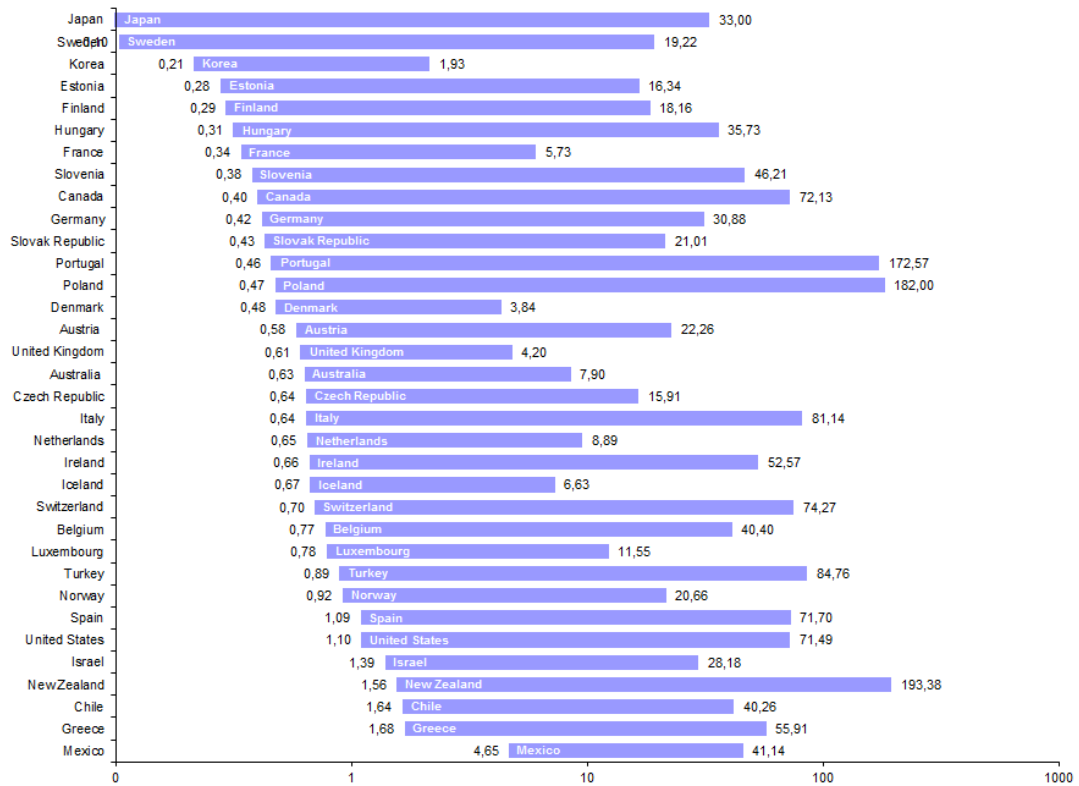
The price for mobile broadband price is also included in the analysis. It is expected that fixed and mobile broadband are substitutes rather than complements, i.e., fixed broadband demand depends negatively on its own-price, whereas demand for fixed-line broadband increases with higher mobile broadband prices. Furthermore, the following relationship between own-price and cross-price elasticities is assumed

$$|\eta_{ff}| > \eta_{fm} > 0,$$

with $\eta_{ff} = \frac{\partial q_f}{\partial p_f} \frac{p_f}{q_f}$ and $\eta_{fm} = \frac{\partial q_f}{\partial p_m} \frac{p_m}{q_f}$, where f denotes fixed-line broadband and m mobile broadband. Since it is rather complex to find an accurate standardized measure for country-level mobile broadband prices because mobile tariffs consist of bundles of voice minutes, texts (SMS), data and so on, mobile tariffs are standardized with the tariff's uncapped data volume in Gigabit per second (Gbps), i.e., a mobile broadband tariff's price is measured in US\$ PPP/Gbps. To facilitate comparisons, the average of the three cheapest tariffs is calculated per country.

Tariff diversity

The recent success of (simple) flat-rate tariffs suggests that simple tariffs may trigger more demand, as they are easily understandable in comparison to more diverse offerings while more complex tariffs may deter consumers from buying. In contrast, classical industrial economics theory suggests that price discrimination in final consumer markets should lead to an expansion of output. The purpose and novelty of this paper is to provide an empirical assessment for how tariff diversity influences broadband demand. As a proxy for a country's tariff diversity the standard deviation of prices in US\$ PPP/Mbps is calculated. Figure 2 shows the price/Mbps ranges in all 34 OECD countries which are related to the newly introduced variable tariff diversity. Thus, we test the classical industrial economic theory that would



Source: OECD, 2012

Figure 2: Fixed broadband prices (US\$ PPP) per Mbps, September 2011

suggest a positive relationship between tariff diversity and fixed broadband demand against the more recently developed behavioral economics view that may suggest a negative relationship.

3.1.2 Explanatory variables

In addition to the three price related variables explained above, the following explanatory variables are included:⁶ First, disposable income is a key determinant of a person's decision to purchase goods and services, and, therefore, it is expected to affect broadband demand positively. Income is represented by GDP per capita in \$US PPP.⁷ However, we cannot directly use GDP in our regression as one has to cope with possible endogeneity issues, precisely reverse causality. The endogeneity problem arises because increased income probably leads to higher investments in infrastructure and increased consumption for technologies, and this in turn can lead to higher GDP (cf. Koutroumpis 2009, Gruber & Koutroumpis 2013). Following Gruber & Koutroumpis (2013) we use one year lags of income as a simple way to tackle the effect of reverse causality. The underlying insight is that broadband adoption influences future GDP after having been adopted, not before. So by using lagged values for income we only measure the effect of income on fixed broadband adoption for which we expect a positive impact.

Second, platform competition is expected to foster broadband coverage, since rivalry between technologies is seen as one important determinant promoting broadband adoption. Moreover, especially in developing countries or isolated areas not all technologies might be available, so this variable also captures the effect that more areas can actually be connected with different technologies. The competitive situation is indicated by a binary dummy variable which equals one if there is at least competition between two technologies in a country, and zero otherwise. Indeed, the data indicates that in countries with competing platforms broadband coverage is on average 10% higher than in countries without platform competition. As a result, inter-platform competition is expected to promote broadband, i.e., to have a positive impact.

The descriptive statistics for the variables are presented in Table 1 and Table 6. In total 91 countries are included for which we see that the number of fixed broadband subscribers is less than 1% in some poor countries, while almost 40% of the population have access to fixed broadband in high-income countries. The monthly price per Mbps differs substantially between countries: in countries with less wired broadband infrastructure a price/Mbps above 2,500 US\$ PPP [150 US\$ PPP/Gbps for mobile broadband] is possible, whereas in some high income countries only about 1 US\$ PPP [0.5 US\$ PPP/Gbps] is paid. The indicator for tariff diversity varies

⁶Table 5 summarizes the included variables' descriptions, expected signs and data sources.

⁷Precisely, in high-income countries, i.e., a country with a larger or equal GDP per capita of 30,000 US\$ per annum, the penetration rate is around 30%, whereas in lower income countries with an annual GDP per capita of less or equal 7,500 US\$ the diffusion is only about 10%.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
BP	10.73	12.53	0.00	39.96	91
PFIX	154.45	349.02	0.95	2527.15	91
PMOB	11.89	21.76	0.51	155.65	85
DIVERSITY	142.23	483.57	0.42	4085.30	91
INCOME	15354.46	15207.85	722.00	57902.00	91
COMPETE	0.73	0.45	0.00	1.00	91
OECD	0.29	0.45	0.00	1.00	91
URBANPOP	59.02	22.99	12.5	100	89
FREEDOM	81.37	49.99	1	175	84

strongly. In some countries prices are very similar, while in other countries there are larger differences in price/Mbps. Moreover, we can infer that in 73% of the countries platform competition is present.

3.2 Estimation Strategy

Demand and supply are assumed to be a function of the following variables

$$\begin{aligned} \text{BP}_i^d &= f(\text{PFIX}_i, \text{PMOB}_i, \text{DIVERSITY}_i, \text{INCOME}_i, \text{COMPETE}_i, \text{OECD}_i), \\ \text{BP}_i^s &= g(\text{PFIX}_i, \text{URBANPOP}_i, \text{FREEDOM}_i), \end{aligned}$$

where $i = 1, \dots, 91$ indicates each market (or country). It is expected that there is a non-linear relationship between the dependent variable and the covariates, precisely,

$$\begin{aligned} \log(\text{BP}_i^d) &= \beta_0 + \beta_1 \text{PFIX}_i + \beta_2 \text{PMOB}_i + \beta_3 \text{DIVERSITY}_i \\ &\quad + \beta_4 \text{INCOME}_i + \beta_5 \text{COMPETE}_i + \beta_6 \text{OECD}_i + \epsilon_i^d. \end{aligned}$$

BP_i^d indicates the number of fixed-line broadband subscriptions per 100 households in country i ,⁸ PFIX_i is the average monthly subscription price in US\$ PPP per Mbps for a fixed broadband tariff. PMOB_i is the mobile tariff monthly subscription price in US\$ PPP standardized by the tariff's data cap. DIVERSITY indicates tariff diversity measured by the price variety in country i , INCOME is approximated by GDP per capita in US\$ PPP, COMPETE is a binary dummy variable that equals one if there is competition at least between two technologies in a country, OECD

⁸Under the category "fixed-line broadband" all fixed-line technologies are subsumed, i.e., are DSL, Cable, Fibre, Satellite, and fixed wireless.

indicates whether a country is an OECD member state or not, and ϵ_i^d is the error term.⁹

For the supply side a positive impact of price on quantity, which is equivalent to a move along a supply curve, as well as a positive effect of the percentage of urban population (URBANPOP) and an economy's freedom (FREEDOM) is expected. Since price and quantities are simultaneously determined, we have to instrument for the price. In the following, we will use the supply shifters as instruments to estimate demand.

3.3 Results

Table 2 reports OLS and 2SLS regression results on fixed broadband demand.¹⁰ The first three columns state the OLS results. Column (1) presents a simple bivariate regression model in which the price level is the only explanatory variable. The coefficient has the expected negative sign and is significantly different from zero at the 1% significance level. Column (2) presents a multiple regression model that also includes the newly introduced variable tariff diversity as an independent regressor. The effect of the price level decreases, but is still significant at the 10% level, whereas tariff diversity and income have a positive impact, the former is significant at the 10% level, the latter at 1%. Finally, column (3) includes all proposed variables, i.e., price, mobile broadband price, tariff diversity, income, competition and OECD membership. The estimated coefficients do not change much: The price still has a negative and significant (10%) impact and income as well as tariff diversity positively and significantly affect the fixed broadband penetration rate (at the 1% and 10% level, respectively). Neither the mobile broadband price nor the level of competition are significantly different from zero. However, in the OLS estimation the price is endogenous in the demand function. Hence, we have to apply instrumental variable techniques and find adequate instrumental variables to account for this endogeneity bias.

To correctly capture the effect of price on broadband demand we employ a 2SLS estimation. We need to find at least one good instrument which affects supply without affecting demand, hence, we are searching for exogenous supply shifters. As instrumental variables we use the share of urban population (URBANPOP) and the Index of Economic Freedom (FREEDOM), which are expected to be unrelated to

⁹The selection of independent variables respond to theoretical considerations and data availability, as well as to the need to keep the number of parameters to be estimated low, given the limited number of observations.

¹⁰All regressions were run using Stata/IC 11.2 for Windows.

the demand side and thus, assumed to be unrelated to the error term. First, urban population is included as a means to reflect differing cost conditions across nations. To serve consumers via fixed broadband a network is needed. The costs of building such a network crucially depend on the distance between the households which are to be connected. Regions with high population density, typically urban areas, can be served more cheaply, whereas sparsely populated areas could only be served at higher prices. The variable is taken from World Bank for 2012 and included in logarithms. Second, since investments are largely specific in a network-based industry, the political and legal conditions are crucial for the supply side. Therefore, the Index of Economic Freedom (FREEDOM) as a second supply shifter is chosen as an instrument. FREEDOM is a measurement for ten freedoms - from property rights to entrepreneurship.¹¹ The index is taken from the Heritage Foundation and ranges from 1 to 186, where 1 is assigned to the freest economy. In an economically free country there would be no constraints on the flow of investment capital and individuals and firms would be allowed to move their resources without restriction. Hence, it is expected that more freedom leads to lower cost and as a result to reduced prices, since resources can be optimally allocated.

Table 7 presents the correlation matrix of the endogenous price variable and the instruments. The table depicts that price is negatively correlated to urban population and positively correlated to the rank of economic freedom, i.e., the less free an economy is, the higher is the price. The former is statistically different from zero at the 1% level, the latter at the 5% level. Table 8 presents the first stage regression results. URBANPOP always has a clearly negative and significant impact on price, while the sign for FREEDOM is ambiguous. To test whether the 2SLS approach indeed improves the biased OLS regression, we use the Hausman test (Hausman 1978) and Sargan J -Statistic. Both tests confirm the validity of our instruments. Thus we conclude that the coefficients obtained from 2SLS are reliable, in contrast to those estimated by OLS which are biased.

The last three columns in Table 2 present the second stage results. Both price *level* coefficients have the expected sign. The coefficient of PFIX is throughout all specifications negative and statistically significant at the 5% level. This indicates, as expected, that countries with lower prices have higher penetration rates. With the 2SLS approach the observed effect of price on broadband demand is considerably larger than the one estimated by OLS. The effect of PMOB is, as before, not significant.

¹¹The Index includes: property rights, freedom of corruption, fiscal freedom, government spending, business freedom, labor freedom, monetary freedom, trade freedom, investment freedom, and financial freedom.

Table 2: Estimation results

Dependent variable: $\log(BP)$						
Variable	OLS			2SLS		
	(1)	(2)	(3)	(1)	(2)	(3)
PFIX	-0.0033*** (0.0012)	-0.0024* (0.0012)	-0.0023* (0.0012){2.18}	-0.0094** (0.004)	-0.0056** (0.0028)	-0.0058** (0.0028)
PMOB			-0.0039 (0.0107){1.20}			0.0115 (0.0143)
DIVERSITY		0.0008* (0.0004)	0.0008* (0.0004){1.85}		0.0023** (0.0011)	0.0023** (0.0011)
INCOME		0.0001*** (0.0000)	0.0001*** (0.0000){1.24}		0.0001*** (0.0000)	0.0001*** (0.0000)
COMPETE			0.1882 (0.4662){1.11}			0.0745 (0.5254)
OECD			0.6356 (0.419){2.28}			0.6825** (0.3162)
Intercept	1.3311***	-0.6316** (0.2937)	-0.6947 (0.4801)	2.3734*** (0.4227)	0.0253 (0.4049)	-0.0939 (0.6761)
N	91	91	85	82	82	78
R ²	0.2236	0.6664	0.6669	-0.7141	0.5174	0.5024
F	7.58	51.14	35.67	5.30	46.52	32.11
Prob>F	0.0072	0.0000	0.0000	0.0239	0.0000	0.0000
Hausman χ^2				13.82 [0.0002]	8.53 [0.0362]	11.25 [0.0466]
Sargan χ^2				0.598 [0.4394]	1.723 [0.1893]	0.975 [0.3235]

Significance levels: * : 10% ** : 5% *** : 1%.

Robust standard errors are reported in parentheses.

Variance inflation factors are reported in curly brackets.

P-values are reported in squared brackets.

The estimated coefficient for tariff *diversity* is positive and significantly different from zero in each specification at the 5% level. Its strong and robust positive impact supports the classical hypothesis that price discrimination leads to an expansion of output, as it allows suppliers to serve low-value customers as well as high-value customers with different prices at the same time. Consequently, we can deduce that firms should have an incentive to offer a range of tariffs with different prices to increase broadband adoption (and profits).

The analysis also shows that income has a positive and highly significant impact on fixed-line broadband demand. Higher income enables consumers to spend more on internet services, and therefore fosters fixed broadband uptake in a country. This finding is confirmed by various other empirical works. Moreover, OECD member states have a significantly higher broadband diffusion rate than non member states. Platform competition is not found to be statistically different from zero. This finding is in line with recent analyses by Calzada & Martínez (2013) and Gruber & Koutroumpis (2013).

Table 3 presents the elasticities for all coefficients for (i) the total sample and (ii) only non-OECD member states.¹² The estimated elasticities confirm that the own-price elasticity is higher than the cross-price elasticity of broadband demand, $|\eta_{ff}| > \eta_{fm} > 0$, as proposed above. Thus, consumers react more strongly to a change in the fixed broadband price than to a change in the mobile broadband price.

Table 3: Elasticities

Variable	Total sample	non-OECD
PFIX (η_{ff})	-0.90	-1.20
DIVERSITY	0.36	0.47
INCOME	1.23	0.77
OECD	0.21	

A 10% decrease in the fixed broadband price can trigger demand to rise by 9% in OECD countries and by 12% in non-OECD countries. An extended range of tariffs by 10%, meaning further tariffs with high prices for more sophisticated users and further tariffs with low prices for below average users, is able to enhance adoption by about 3.6% (total sample) and 4.7% (non-OECD), respectively. If income in OECD countries is increased by 10%, fixed-line broadband coverage is increased by 12.3% and by around 8% in non-OECD countries.

¹²All elasticities are calculated at the means of the independent variables.

4 Discussion and Conclusion

The present paper has determined factors that influence the adoption of broadband internet access and that help to explain the observable patterns of broadband penetration in different countries. In particular, it has been examined how tariff diversity influences broadband uptake which has not been analyzed before.

For the estimation of fixed-line broadband penetration in 91 countries an entirely new data set was used, which includes nearly 1500 fixed-line and more than 2000 mobile broadband tariffs. Based on a 2SLS approach, which remedies the endogeneity problem that is present in a simple OLS regression, the analysis shows: Firstly, the fixed-line broadband price level crucially matters, it is negatively related to demand in all specifications. Secondly, the newly introduced variable tariff diversity, which measures the standard deviation of tariffs, significantly enhances demand. The possibility of price discrimination seems, as suggested by traditional economic theory, to enlarge output and demand by serving consumers with a low willingness-to-pay. Thirdly, income and, fourthly, OECD membership positively influence adoption. The positive coefficient of income and OECD membership indicate that fixed broadband penetration tends to be higher in wealthier economies; again this result is robust. Lastly, the estimated coefficients for mobile broadband price level and inter-platform competition had the expected positive signs, but were insignificant.

These findings indicate that primarily price related factors and socio-economic effects determine fixed broadband penetration. The results also suggest that reduced prices and increased tariff diversity are a more important channel of fixed broadband adoption than increased inter-platform competition. As a policy matter, these results suggest that policy makers should be lenient towards price discrimination in broadband markets.

The estimated model works quite well for a cross-sectional regression of heterogeneous countries with the majority of non OECD countries. The results, e.g., that tariff diversity enhances fixed broadband adoption, seem to be especially true for emerging markets and may have a decreasing impact in more mature markets. It is worth pointing out that, despite good results, there are some limitations of this empirical analysis which should be kept in mind. Aggregated data at a national level is used which makes it impossible to account for differences within a country. This is an important aspect that has also been pointed out by other authors in the literature (e.g. Kim et al. 2003, Garcia-Murillo 2005). Further, more detailed data on the level of competition would be desirable, but was unfortunately not available,

and finally, broadband adoption, like any process of technology diffusion, is seen as a dynamic development. Such a process of adoption evolves through time and this feature can not be taken into account in a cross-sectional estimation model. Consequently, using time-series data in future research should be eligible.

In conclusion, the results obtained by the model provide some useful insights and point to the importance of factors that are often overlooked in broadband policy, namely tariff diversity, i.e., the range of tariffs' prices/Mbps offered in a country. Given the above-mentioned necessary assumptions and data limitations, further evaluation to confirm the importance of tariff diversity with time-series data should be aspired.

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Appendix

Table 4: Broadband penetration and prices by country

Country	fixed broadband user (in %)	internet users (in %)	Price/Mbps (in US\$ PPP/Mbps)
Afghanistan	-	5.00	687.88
Algeria	2.78	14.00	45.63
Angola	0.13	15.00	114.65
Argentina	10.54	47.70	34.48
Australia	24.32	79.00	4.97
Austria	25.42	79.80	2.16
Azerbaijan	10.73	50.00	144.22
Bangladesh	0.31	5.00	1370.15
Belarus	21.94	39.60	20.46
Belgium	32.95	78.00	1.17
Benin	0.43	3.50	335.81
Bolivia	0.65	30.00	512.26
Brazil	8.59	45.00	8.60
Bulgaria	16.45	51.00	1.49
Burkina Faso	0.08	3.00	268.12
Cambodia	0.15	3.10	101.73
Cameroon	0.01	5.00	654.18
Canada	31.83	83.00	2.77
Chile	11.60	53.90	7.74
China	11.61	38.30	6.59
Colombia	6.94	40.40	17.47
Cote d'Ivoire	0.25	2.20	286.55
Czech Republic	15.84	72.90	4.89
Denmark	37.60	90.00	1.99
Dominican Rep.	4.02	35.50	29.32
Ecuador	4.22	31.40	12.02
Egypt	2.21	38.70	35.67
El Salvador	3.31	17.70	22.94
Finland	29.50	89.40	4.27
France	36.04	79.60	2.12
Germany	33.09	83.00	2.67

Ghana	0.25	14.10	440.44
Greece	21.62	53.00	3.66
Guatemala	-	11.70	60.16
Honduras	0.43	15.90	31.19
Hong Kong, China	31.58	74.50	1.21
Hungary	22.16	59.00	3.32
India	1.08	10.10	32.30
Indonesia	1.13	18.00	180.04
Iran (Islamic Rep.)	2.37	21.00	206.30
Israel	24.85	70.00	2.27
Italy	22.08	56.80	2.16
Japan	27.60	79.50	2.58
Jordan	3.16	34.90	61.62
Kenya	0.10	28.00	185.45
Korea (South)	36.91	83.80	0.95
Kyrgyzstan	0.69	20.00	154.26
Lao P.D.R.	0.66	9.00	91.63
Libya	1.09	17.00	36.53
Madagascar	0.03	1.90	186.16
Malaysia	7.44	61.00	48.62
Mali	0.01	2.00	258.13
Mexico	10.21	36.20	12.10
Morocco	1.83	51.00	4.28
Nepal	0.31	9.00	106.07
Netherlands	38.74	92.30	1.39
Nicaragua	1.45	10.60	19.35
Niger	0.01	1.30	386.57
Pakistan	0.42	9.00	38.42
Papua New Guinea	0.11	2.00	2527.15
Paraguay	0.92	23.90	98.55
Peru	4.05	36.50	1161.01
Philippines	1.89	29.00	39.95
Poland	14.68	64.90	6.45
Portugal	20.95	55.30	1.77
Saudi Arabia	5.62	47.50	19.97
Senegal	0.73	17.50	72.39
Serbia	11.29	42.20	20.12

Singapore	25.63	71.00	2.27
Slovak Republic	13.65	74.40	2.22
Slovenia	24.34	72.00	6.23
South Africa	1.80	21.00	86.93
Spain	23.78	67.60	1.86
Sri Lanka	1.71	15.00	36.01
Sudan	0.04	19.00	165.23
Sweden	31.77	91.00	2.23
Switzerland	39.96	85.20	3.28
Syria	0.58	22.50	66.84
Taiwan, China	23.71	72.00	8.33
Tajikistan	0.07	13.00	97.60
Tanzania	0.01	12.00	489.97
Uganda	0.10	13.10	985.96
Ukraine	7.01	30.60	9.02
United Arab Emi- rates	10.99	70.00	61.21
United Kingdom	32.74	82.00	0.97
United States	27.35	77.90	3.32
Uzbekistan	0.53	30.20	222.39
Venezuela	6.17	40.20	46.90
Yemen	0.44	14.90	184.99
Zambia	0.06	11.50	218.16
Zimbabwe	0.27	15.70	103.75

Table 5: Variable description and source

Variable	Description	Sign	Source
BP	Fixed broadband penetration, number of subscriptions per 100 inhabitants.		ITU, 2012
PFIX	Fixed broadband tariffs' monthly price standardized by the download speed offered to price per Mbps (in US\$ PPP/Mbps).	-	Google, 2012
PMOB	Mobile broadband tariffs' monthly price until data cap (in Gbps) is reached (in US\$ PPP/Gbps).	+	Google, 2012
DIVERSITY	Tariff diversity in a country. Measured by standard deviation of PFIX.	+	Google, 2012
INCOME	Annual GDP per capita in US\$ PPP.	+	World Bank, 2011
COMPETE	Binary dummy variable whether there is at least competition between providers of different technologies; equals 1 if there is platform competition, 0 otherwise.	+	Google, 2012
OECD	Binary dummy variable indicating OECD membership; equals 1 if country is a member state, 0 otherwise.	+	OECD, 2012
URBANPOP	Urban population per 100 inhabitants.	-	World Bank, 2012
FREEDOM	Index that measures economic freedom in 186 countries, the freest country is assigned the first rank out of 1-186.	+	The Heritage Foundation, 2011

Table 6: Cross-correlation

Variables	log(BP)	PFIX	PMOB	DIVERSITY	INCOME	COMPETE	OECD
log(BP)	1.000						
PFIX	-0.473***	1.000					
PMOB	-0.299***	0.351***	1.000				
DIVERSITY	-0.198*	0.666***	0.134	1.000			
INCOME	0.776***	-0.342***	-0.237**	-0.193*	1.000		
COMPETE	0.310***	-0.087	-0.179	0.000	0.324**	1.000	
OECD	0.622***	-0.275***	-0.212*	-0.182*	0.716***	0.335***	1.000

Significance levels: * : 10% ** : 5% *** : 1%.

Table 7: Cross-correlation of instrumental variables

Variables	PFIX	URBANPOP	FREEDOM
PFIX	1.000		
URBANPOP	-0.443***	1.000	
FREEDOM	0.274**	-0.501***	1.000

Significance levels: * : 10% ** : 5% *** : 1%.

Table 8: First stage estimation results 2SLS

Dependent variable: <i>PFIX</i>			
Variable	(1)	(2)	(3)
URBANPOP	-396.2074** (170.1083)	-380.4275** (169.0788)	-403.4237** (156.1059)
FREEDOM	0.2205 (0.5127)	0.5598 (0.3407)	-.0659 (.4694)
PMOB			4.0535 (3.272)
DIVERSITY		0.4337*** (0.1277)	0.411*** (0.1161)
INCOME		0.0037 (0.0029)	0.0042* (0.0025)
COMPETE			34.7782 (64.7709)
OECD			-22.5255 (28.3101)
Intercept	1726.585** (730.6462)	1514.948** (643.9144)	1583.977*** (575.0665)
N	82	82	78
R ²	0.2952	0.6524	0.7077
F	4.93	13.53	7.88
Prob>F	0.0096	0.0000	0.0000

Significance levels: * : 10% ** : 5% *** : 1%.

Robust standard errors are reported in parentheses.