Economics aspects of migration to fibre and potential welfare gains and losses from an uplift to copper prices

Prof. Carlo Cambini[1]

Politecnico di Torino

Florence School of Regulation - European University Institute

Paper Prepared for the New Zealand Commerce Commission

March 16, 2015

*****

Introduction

Given the huge relevance of prompt deployment of fibre networks, regulators around the world are increasingly concerned by how to create the right incentive for accelerating infrastructure adoption in the telecom market.

Faster broadband connections call for large capital expenditures, attracting regulatory concerns about third party access to these networks. Following for example the EU Recommendation C(2010) 6223 on regulated access to Next Generation Access Networks (September 2010), in Europe, national regulatory authorities have been adopting a new set

[1] Department of Management – Politecnico di Torino, Corso Duca degli Abruzzi, 24, 10129 Turin, Italy. Tel: +39 011 5647292; fax: +39 011 5647299. Also affiliated to the Florence School of Regulation, Robert Schuman Center – European University Institute, Florence. E-mail: carlo.cambini@polito.it

of regulatory rules on network access which is intended, on the one hand, to avoid re-monopolization of the market for high-speed broadband services, and, on the other hand, to provide enough incentives to invest in high speed infrastructures to both incumbent and entrant operators.

Recent debate in telecoms industry is focusing on the role of access regulation to the legacy copper network in creating such incentives to invest. Access regulation, mainly local loop unbundling, is unanimously regarded as an effective pro-competitive measure and has been consistently used by regulators as an instrument to encourage entrants to climb the so-called "stepping stone" or "ladder of investment" (Cave and Vogelsang, 2003). More recently, Cave (2010) extends his analysis on the ladder of investment over NGA networks and discusses the impact of the introduction of fibre unbundling. Inspired by some recent empirical evidence (Waverman *et al.*, 2007; Grajek and Roller, 2012) he argues that, in order to provide incentives to alternative operators to climb the last rung of the ladder (i.e. invest in own fibre network), an increase in the price of wholesale access charges on legacy copper lines would be desirable. His reasoning goes as follows: if the price of the local loop unbundling increases, the alternative operators would be more inclined to invest in their own infrastructures, encouraging the deployment of proprietary fibre networks. The underlining assumption of Cave (2010)'s analysis is that an increase in the price of ULL provides, under all circumstances, an incentive for alternative operators to invest in own infrastructures.

In New Zealand the government has subsidized the deployment of an Ultra-Fast Broadband (UFB) network, which is a FTTH, and will cover 75% of the population. Recently, the New Zealand government has also indicated to seek bids for further expanding the UFB coverage from 75% to 80%. The UFB network is contractually committed and is operated on a wholesale-only basis; a contractual requirement of the UFB is that it must be capable of being unbundled. This implies that, differently from what we observe in Europe, the key policy point in New Zealand is not how relative copper and fibre prices will affect incentives to invest in fibre, but rather how they will affect the migration of end users between the networks and what the benefits from accelerated migration might be.

The peculiarities of the New Zealand's case – with a vertically separated infrastructure operator, Chorus – makes the above mentioned "ladder of investment" concept relevant in terms of alternative operators potentially moving from Layer 2 access (bitstream) to Layer 1 access (unbundling) but not for "stepping off" the last rung and bypassing the fibre loop (Layer 1).

In this framework, on 2 December 2014, the New Zealand Commerce Commission (hereafter Com Com) released for consultation its draft pricing review determination for Chorus' unbundled copper local loop (UCLL) service[2]. In the UCLL draft determination, the Commission set a draft UCLL price of $28.22 per month, which was based on the results of a TSLRIC model. The Commission also issued a draft pricing review determination for Chorus' unbundled bitstream access (UBA) services[3], setting a draft price for the UBA service, of $10.17 per month for the incremental bitstream component. The combined draft price of the UCLL and UBA service is therefore $38.39 per month.

It is my understanding that, following the publications of the UCLL draft determination, the Commission has been undertaking some quantitative analysis of the potential welfare effects that could arise in the event that an uplift were added to the central TSLRIC estimate of the UCLL price.

The aim of this document is to assess the potential welfare effects of such uplift and review a draft of the analysis done by Com Com. In particular, the scope of this document is the following:

i. Review and provide comments on the approach proposed by the Commission as set out in the attached "Analysis of potential welfare gains and losses from an uplift to copper prices"
ii. Identify and provide any additional source material (empirical studies, research etc.) relating to parameters used in the document "Analysis of potential welfare gains and losses from an uplift to copper prices", in particular:

[2] Commerce Commission "Draft pricing review determination for Chorus' unbundled copper local loop service", 2 December 2014, available at http://www.comcom.govt.nz/regulated-industries/telecommunications/regulated-services/standard-terms-determinations/unbundled-copper-local-loop-and-unbundled-bitstream-access-services-final-pricing-principle/

[3] Commerce Commission "Draft pricing review determination for Chorus' unbundled bitstream access service", 2 December 2014, available at above link.

a. Cross-price elasticity of fibre demand with respect to DSL prices (see paragraph 10.c of the attached);
b. Value of externalities (Table 2 of the attached)

iii. In considering the potential effect of an increase in copper prices on fibre demand, provide comments on the importance of relative prices between fibre and copper, including
a. whether there is any evidence of a 'tipping point' (for example, where fibre demand becomes very elastic with respect to DSL prices);
b. Whether there is any evidence on consumers' willingness to pay for higher quality services over fibre.

In the next Section I provide comments and suggestions on the Com Com's analysis and present new insights and evidences that could be useful to eventually expand the current draft of the study. In the Appendix I also report a brief review of the literature on the economics of migration from copper to fibre networks, that is mostly focused on the interplay between copper access prices and incentives to invest in fibre network, which is not the central issue in the New Zealand case.

1. A review of Com Com's "Analysis of potential welfare gains and losses from an uplift to copper prices"

The main theoretical economic literature on migration to fibre focuses on the impact of access prices to the legacy copper network on the incentives to invest on the fibre infrastructure (see the Appendix). The typical scenario envisaged in the analysis is the EU one where the infrastructure operator is also integrated downstream in the retail broadband segment and Government intervention in sustaining fibre infrastructure is somehow limited.

As noted in the Introduction, this is not the case in New Zealand. In fact, the Ultra-Fast Broadband (UFB) network is contractually committed and subsidized by the government.

This implies that the key issue to consider when assessing a regulatory policy in the New Zealand scenario is not the impact of copper prices on the incentives to invest in fibre, but rather the effect of copper prices on migration of customers from copper to fibre services.

The New Zealand Commerce Commission is currently in the process of assessing the potential welfare effects of an uplift of the copper-based access price to ULL. The Com Com is seeking an economic opinion on their first draft of the welfare analysis that is based on the following main assumptions:

a. the central TSLRIC estimate of the monthly recurring charge of $28.22 is increased by $1;

b. the $1 increase in the wholesale UCLL price is fully passed through into the retail prices of those copper-based services that rely on the UCLL service (including both retail DSL and POTS services);

c. the increase in the retail price for copper-based services leads to increased demand for fibre-based services (with the extent of customer switching based on a cross-elasticity of demand for fibre with respect to DSL prices of 1.2);

d. The benefits and costs are assessed over a 10-year timeframe, with a discount rate of 10%.

The methodology used is overall correct, but I believe that some key assumptions could be slightly revised to better account of the benefits of fibre investments. Moreover, it seems to me that some potential benefits from UFB deployment have not been completely considered. Below I list my detailed comments and suggestions.

In general, it is my opinion that the full pass-through of the UCLL uplift to the retail DSL prices is correct: the underlining assumption is that the retail market for copper-based broadband services is substantially competitive and therefore every increase in the cost of input is translated in a higher cost of the output. This effect is also supported by recent companies' evaluation. Telefónica de Espana – the Spanish incumbent - submitted a report to the EU investigating the effect of a reduction in wholesale prices on retail prices for

ADSL.[4] The study aims at estimating the "pass-on-elasticity" of a change in the wholesale price of loop access with respect to the price of broadband, considering the different ADSL connection speeds. Using an ordinary least squares regression, the study shows that pass-on elasticity is always positive (as expected), but it is greater for higher broadband connection speeds. Pass-on elasticity is 0.45 for low-speed connections (144kb – 1.99MB), 0.60 for medium-speed (2MB – 9.99MB) and 0.91 for high-speed connections (10MB or more). This evidence suggests that for high-speed connections – in the analysis mostly DSL connections but in the perspective of the Com Com analysis a proxy for fibre connections - changes in access prices will pass through almost entirely into changes in retail prices.

The timeframe of the analysis seems to be too short. A huge investment in new fibre infrastructures will last for a much longer period than 10 years. I understand perfectly that a regulator should carefully balance static and dynamic efficiency but I would eventually add simulations with, say, a 15 years' timeframe or 20 years timeframe just to check if with a longer period the results remain unchanged.

In the following subsections I will instead provide more detailed suggestions on three relevant issues:

i) the degree of cross-price elasticity between fibre uptake and the retail price of copper-based (DSL) services;
ii) the value of network externalities in fibre adoption;
iii) potential missing elements in the current assessment;
iv) The evaluation of consumers' willingness to pay for very high speed connections.

2. Cross –price elasticity of fibre demand with respect to DSL prices

The welfare analysis presented by Com Com assumes a cross price elasticity of the demand of fibre with respect to DSL retail price equal to 1.2. This number comes from an

[4] Solchage Recio & Asociaos (Strategic & Economic Consulting) Nov 2011, "Analysis of the relationship between wholesale and retail internet access prices". Submitted as Annex 3 of Telefónica's response to the EC Costing Methodologies Questionnaire. Cited in Dot.Econ (2012) "Regulatory policy and the roll out of fibre to the home networks", prepared for the FTTH Council Europe, July.

estimation analysis by Shinohara et al. (2011) over 30 OECD countries during the period 2000-2009; this paper presents evidence of a cross-price elasticity between DSL price and FTTx connections equal to 1.189.

The economic literature has scant evidence on the value of this cross elasticity. I list below some further studies found in the specialized economic literature.[5]

In the paper by Srinuan et al. (2012), the authors develop an empirical investigation to analyze the direct and cross-price elasticity among different types of broadband technology (xDSL, cable, Fibre, mobile BB). Data was obtained from a random nationwide postal mail survey of Swedish households during August and September 2009 with around 2038 respondents. Using a simple discrete choice model,[6] results show that the cross-price elasticity of demand for fibre in relation to DSL price is 3.289.

Using a similar database, Bohlin (2012)[7] also analyze the substitutability between broadband technologies in different areas of Sweden. Results show that in areas where all 4 platforms are available, cross-price elasticity ranges between 0.219-0.945, while, in areas where cable is not available, cross-price elasticity ranges between 0.370-0.845. In this latter case, the author reports that fibre connections are less sensitive to change in price with respect to other connection types. This implies that fibre presents a cross-price elasticity effect that is less than 0.945.

Finally, a recent study by Grzybowski et al. (2014) uses a large database from a survey of 6,446 households in Slovakia during April – July 2011 to estimate own- and cross- price elasticity of demand for 5 broadband technologies (DSL, fibre, cable, FWA, and mobile

[5] There are some old studies based on 2000-2001 data, but they do not refer to fibre technology. A sum up of these analyses could be found at: https://books.google.co.nz/books?id=fkpyVLy_RJ4C&pg=PA106&lpg=PA106&dq=cross+price+elasticity+of+fibre+and+dsl&source=bl&ots=6O8TraO0W0&sig=hHtlAdUYV0a3lERpR4_YxuyEchU&hl=en&sa=X&ei=fv7jVIrMDqG1mAXSzIHYBA&ved=0CCwQ6AEwAg#v=onepage&q=%22cross%20price%20elasticity%22&f=false

[6] The paper uses the simplest multinomial logit model, which generates flexible aggregate substitution patterns when household characteristics are among choice determinants. However, this method could lead to possible estimation errors especially when there is a lot of unobserved household heterogeneity.

[7] Available at http://www.wik.org/fileadmin/Konferenzbeitraege/2012/Mobile_broadband/Erik_Bohlin_WIK_presentation-v5.pdf

BB). Using a more sophisticated mixed logit discrete choice model,[8] results show that an 1% increase in DSL price would increase demand for fibre by between 0.66% (at country level) and 0.96% (at municipality level), indicating a cross-price elasticity of demand for fibre in relation to DSL of 0.66-0.96.

All in all, the evidences provided show that cross-price elasticity ranges from the lower bounds found in Grzybowski et al. (2014) of 0.66-0.96, to the value of 1.189 found in Shinohara et al. (2011) and to the upper bound of 3.2 found in Srinuan et al. (2012).

These values are also consistent with my own experience and research results. I am also personally involved in a research project join with Prof. Briglauer (ZEW, Mannheim) about the effects of migration on the incentive to adopt fibre connections by EU citizens. The project is at the starting phase and unfortunately our results are still very preliminary. However, using data from EU27 over the period 2004-2013, our first results show the presence of a cross-substitution between a change in the DSL price and the adoption of fibre connection ranging between 0.6-0.64, in line with the lower bound found in Grzybowski et al. (2014).

Note that all the above mentioned studies use sophisticated econometric methods but they are based on different sources of data: the analysis by Srinuan et al. (2012), Bohlin (2012) and Grzybowski et al. (2014) are based on surveys from a single country, while the analysis by Shinohara et al. (2011) as well as mine, are based on cross country investigation. In the latter studies, potentially unobserved cross-country heterogeneity as well as price dynamics might affect the final results and somehow depress the values of the cross-price elasticity. Analyses based on end user surveys are instead better in isolating the relative price effect of a change in the DSL prices on fibre connections, but they are highly sensitive to the state of knowledge of the alternatives among which end users can choose. On this respect, the paper by Grzybowski et al. (2014) uses an ad hoc methodology to limit such drawbacks. It is rather difficult to say that one method is better than the other one since in my opinion both methods could bring to reasonable results when the estimation models adopted are

[8] Mixed logit model allows for rich substitution patterns across consumer choices, in our case technology adoption, especially when there is a lot of unobserved household heterogeneity. Its main drawback is that this method imposes specific functional assumptions.

robust. In sum, I can state that a cross-price effect in the range of 1.2 is a fair and reasonable average of the values found in recent economic literature.

Finally, note that I did not find any evidence of the presence of a 'tipping point' or a change in the degree of elasticity of fibre demand with respect to DSL prices.

3. The role and the value of network externalities

Network effects are a special type of externality related to fibre adoption process. Indeed, increases in the adoption rates lead to increases in the usage intensity of the respective services (Grajek and Kretschmer, 2009). Consumers' utility can be related to the possibility of communicating with one another at the consumer level either directly, e.g. via different "Web 2.0" platforms, or indirectly, in the case of network effects occurring at different producer levels. For instance, the more users subscribe to (high-speed) Internet services, the more specific content and related applications will be programmed, which increases the consumers' utility and willingness to adopt such services. Moreover, operators simply benefit from the network size, since an increase in the total number of subscribers lowers the average costs significantly in view of the fibre network topology and thus increases the profits.

This implies that an analysis of the network externalities generated by fibre deployment is important. In the current draft of Com Com's document, the regulator estimates the value of network externalities starting from an Ofcom (2004)'s document on mobile termination where the UK regulator introduced a specific component into the termination charge to spur network externalities within mobile networks. Com Com quantifies this effect in around 2% of retail expenditures. Though technically correct, I simply note that the presence of network externalities should directly affect the demand and indirectly the cost. Therefore, drawing for the existing empirical literature on broadband adoption, and more specifically on fibre adoption, I will provide below suggestions on how Com Com could eventually revise, or at least test the robustness of, its analysis to consider directly an impact on subscribers (the demand side) rather than indirectly through costs.

To my knowledge, there are two sets of papers to consider: the first one deals with broadband service adoption; the second one specifically accounts for broadband take up in fibre infrastructures.

In the first set of papers, we can mention Bouckaert et al. (2010), Lee and Lee (2010), and Lin and Wu (2013). Though not directly related to fibre adoption, they may provide interesting evidence on the existence of network externalities and on their values.

Bouckaert et al. (2010) and Lee and Lee (2010), using data from OECD countries, found that the penetration in the previous time period significantly and positively affects current broadband penetration. The former study suggested that the result verifies the positive persistence of the penetration overtime, while the latter one suggested that it is positive network effect, indicating that a higher current subscriber number attracts more subscribers in the future. In Bouckaert et al. (2010) the estimated coefficient for lagged penetration is 0.96. No matter what the explanation is, these studies confirm the positive significant effect of previous broadband penetration and this result reveals that a higher penetration in the current year results in a higher penetration in the next year.

Lin and Wu (2013) study the determinants of broadband diffusion by applying the Arellano–Bond generalized methods of moments (GMM) dynamic panel-data estimation with a more complete period from 1997 to 2009, by using a Gompertz diffusion model. The idea to use a dynamic econometric methodology is linked with the idea to capture the dynamic of broadband development. In this analysis, the dependent variable is broadband penetration, measured as total fixed broadband subscribers per 100 inhabitants (in log), and the broadband technologies adopted by the subscribers include DSL, cable, fibre, satellite, and fixed wireless. The analysis shows that the estimated parameter of lagged broadband penetration ranges between 0.25 – 0.54. This implies that a 1% increases in previous broadband subscribers generates, everything being equal, a positive effect on future subscribers equal to 0.2-0.5%.

The only paper that analyses the presence of a network externality effect on fibre adoption is Briglauer (2014). Based on an unbalanced panel of the EU27 member states for the years from 2004 to 2012, the paper employs both static and dynamic model specifications and identifies the most important determinants of the adoption of fibre-based broadband services.

Data comes from the "EU Progress Report", the database of FTTH Council Europe, EUROSTAT/COCOM as well as the International Telecommunications Union (ITU).

In this paper, the author determines the so called speed of diffusion of fibre adoption. This index is expressed as the percentage of the gap between the long-run (desired or target) stock of fibre subscribers and the subscribers in the previous period that is closed each period. In some sense, considering the dynamic nature of the analysis, the author determines a sort of long-term trend of adoption that is relevant to evaluate network externalities.

The results of Briglauer (2014) show that the estimated coefficient for the previous period fibre users lies in the range between 0.56-0.78 with a media value of 0.70. This result implies that the speed of diffusion of fibre is equal to 1 – 0.70 = 0.30.

According to the author this result has the following interpretation: the gap between the average number of fibre connections per household (0.05147) and the EU Digital Agenda's target value (0.5) is covered with an increase of 30% per year. Hence, in the first period, 30% of the gap (0.5-0.05) is closed, i.e. 0.45*0.3. In the second period the remaining gap is (0.5-0,185) and again 30% of this gap will then be closed on so on.

This analysis is based on the assumption of a fixed target that is constant over time. It is my opinion that the same results could be interpreted saying that a 1% increase in fibre adopters in year *t*-1 generates a positive effects on fibre users in year *t* equal to 0.7%, everything being equal.

By employing this factor into the estimated UFB demand with UCLL uplift presented at page 14 of Annex 1 you will the following values:

	No UCLL uplift (a)	*% change*	*Network effect % change (b)*	*No UCLL uplift Adjusted (c)=(a)*(1+(b))*	*UCLL uplift (d) = (c)*(1+1.52%)*	*Delta (d) - (a)*
2015	100000	-	-	100000	101520	1520
2016	200000	1.00	0.70	340000	345168	145168
2017	300000	0.50	0.35	405000	411156	111156
2018	400000	0.33	0.23	492000	499478	99478
2019	500000	0.25	0.18	590000	598968	98968
2020	600000	0.20	0.14	684000	694397	94397
2021	700000	0.17	0.12	784000	795917	95917
2022	800000	0.14	0.10	880000	893376	93376
2023	900000	0.13	0.09	981000	995911	95911
2024	1000000	0.11	0.08	1080000	1096416	96416

This implies that by 2024 under the "UCLL uplift" scenario with adjustment, the number of UFB subscribers becomes 1,096,416 while under the "No UCLL uplift" scenario it reaches 1,080,000 at the same date. Hence, under the "UCLL uplift" scenario the number of 1,080,000 users is reached slightly in advance than 10 years, i.e. after 9.84 years (i.e. 0.16 year earlier), implying a 'bring forward' benefit of 1.57%, i.e. (1+10%) ^0.16 -1.

4. A potential missing element: the external long term benefits

Worldwide there are ample examples of NGA build-out with low customer take-up. The question therefore is if much welfare is lost by slower rather than faster build-up of NGA coverage. The answer depends on whether the external benefits of broadband infrastructure extend to the incremental move from broadband to NGA.

It seems to me that there is a further potential external effect of investment in fibre infrastructures. It is true that part of the financial resources will be paid by the Government (around NZ$ 1.3 billion over a total investment of NZ$ 4-5 billion, approximately 30%)[9], but still investment in broadband and ultra-broadband infrastructures is considered to provide a significant contribution to economic growth. Increasing national GDP in turn affects consumers' per capita income that in turn may further shift UFB demand outwards.

[9] See https://secure.zeald.com/site/nzinitiative/files/Delivering_on_the_broadband_aspiration.pdf

Many papers quantify the macroeconomic effects of investment in broadband fixed infrastructure (including however not only fibre but also xDSL). To limit the sum up to more recent evidences, Koutroumpis (2009) indicates that the average impact of broadband infrastructure on GDP is 0.63% (for the EU-15, in the period 2002-2007), that is, 17% of total growth in the timeframe of the analysis. He also finds that there are increasing returns from broadband investments once a critical mass is reached.

Greenstein and McDevitt (2009) estimate that broadband accounted for $28 billion of US GDP in 2006, and that $20 to $22 billion of US GDP were associated with household use of broadband.

Czernich, Falck, Kretschmer, and Woessmann (2011) find that, after a country has introduced broadband, GDP per capita is 2.7 to 3.9 percent higher on average than before its introduction. In terms of subsequent diffusion, a 10 percentage point increase in broadband penetration raises annual per-capita GDP growth by 0.9 to 1.5 percentage points.

The only study that focuses on the impact of faster broadband investment is the report prepared for the UK Department for Culture, Media & Sport (2013).[10] The report shows that economic impact of take-up of faster broadband speeds will add about £17 billion to the UK's annual *Gross Value Added* (GVA)[11] by 2024. This level of uplift contributes an average of 0.07 percentage points to real annual GVA growth over this period. According to the analysis, the GVA impacts attributable to the current set of publicly funded interventions rise to about £6.3 billion per year by 2024, which is equivalent to an uplift of 0.03 percentage points on the UK's real annual GVA growth. Over the time period of the analysis (to 2024), these interventions are supposed to generate a high multiplicative effect of approximately £20 in net economic impact for every £1 of public investment. The bulk of this economic impact comes from improvements in the productivity of broadband-using firms, but there are also significant benefits from safeguarding employment in areas which would otherwise be at an unfair disadvantage, from productivity-enhancing time-

[10] "UK Broadband Impact Study. Impact report", Novembre 2013. Prepared by the consulting company SQW, London. Avaialble at: https://www.gov.uk/government/publications/uk-broadband-impact-study--2

[11] According to the report, *Gross Value Added* is a measure of economic output. It is closely linked to Gross Domestic Product, as follows: GVA + taxes on products - subsidies on products = GDP .

savings for teleworkers, and from increased participation in the labor force. In particular, the authors of this study show that the main relevant social impact of expanding fibre connections is the reduction in digital divide. Besides the digital divide issue, there are many other potential social impacts associated with the availability and usage of faster broadband for end users. Among all possible impacts, the report considers: a better connectivity to support communications and the networking of people and content; a faster use of on line entertainment, ecommerce, e-government and e-health services.

However, the authors report that "the complex and changing nature of the interactions between people and technology mean that many of these social impacts are impossible to forecast with any degree of confidence" (page 4).

The evidence on the impact of adoption of (standard, not fibre) broadband connections is rather mix, country specific and somehow inconclusive. In the UK, the consulting company SQW estimated that the direct (gross) financial benefits of broadband connections (though not fibre) in the home, mostly through reduced household spending were about £70 per month for the average UK household, ranging from £23 per month for the 10% of households with the lowest income to £148 per month for the 10% with the highest incomes (SQW 2008). For the US, Greenstein and McDevitt (2009) estimated a quality-adjusted consumer surplus of $95 billion in 2009, whereas Dutz et al. (2009) find a consumer surplus for that year at $32 billion. Note that all these studies consider the adoption of standard broadband but not faster connections.

More generally, in all of the above mentioned studies it is rather difficult and contentious to split these figures into benefits accruing to users through the economy as a whole (for example, in terms of higher GDP per capita or higher employment) and benefits accruing to end users in their role as "telecom" end users adopting faster connections. All in all, we can claim that these wider external benefits would be largely beyond the more direct benefits for end users of telecommunication service.

I see two ways to eventually account for these wider external benefits:

- first, by adding such aggregate effect to the benefit of the welfare analysis;

- second, by adding to the UFB demand a further shift related to the increase in GDP per capita; Bouckaert et al. (2010), for example, show that per capita national income (measured in 1000 US$ in 2006 purchasing parity) has a positive and significant effect on broadband penetration. In this study, the dependent variable is total broadband penetration, i.e. the total number of broadband connections per quarter/country as a share of the total number of households, and expressed as a percentage. The estimated coefficient is equal to 0.048 when the presence of network externalities is accounted for (this implies that there would be no duplication in adding the two effects). Hence, according to this paper, an increase of US$ 100 for each user would raise the broadband penetration of roughly 4.8 percentage points. This effect is also present in Lin and Wu (2013); in this paper the dependent variable is the logarithm of the broadband penetration, measured as total fixed broadband subscribers per 100 inhabitants and the income per capita is expressed in US$. Results show that in an early stage of development of broadband adoption – close to the current situation in fibre adoption – this coefficient is quite large, equal to 6.01, and then it reduces to 0.48 and 0.52 in later stages of broadband development. This result implies that an increase in per capita income would raise broadband penetration in the early phase of development quite considerably (more than 100%). Though maybe too huge and probably not useful for simulation, this paper confirms the positive effect of income on broadband adoption.

  Finally, in Briglauer (2014) the effect of income on fibre adoption is never significant at the conventional values, meaning that when looking specifically to (EU) fibre adoption income seems not to play any role in spurring fibre adoption.

Considering the ambiguity of the existing results from the empirical literature on the impact of GDP per capita on broadband adoption, the first option listed above may be safer for considering a quantitative effect of external long term benefits. Alternatively, you should account for the fact that your current Analysis is *gross* of these external benefits.

5. The willingness to pay for ultra-fast broadband services: some evidence

It is rather difficult to predict and estimate the willingness to pay of consumers for very high speed connections. Clearly, fibre connections with high speed have a higher quality than copper-based services and this in turn would imply that on average the willingness to pay for this product differentiation should be larger.

Unfortunately, there exists few economic documents that present robust analysis on the willingness to pay for migrating from copper to fibre connections, i.e. in estimating the so called "fibre premium". Most of this evidence suggests that customers are likely to have high incremental willingness to pay for a high speed service, but a low incremental willingness to pay for a very high speed.

Using data from a nationwide US survey administered during late 2009/early 2010, Rosston et al. (2010) estimate a random utility model of household preferences for broadband Internet services, offering different grades of speed (slow, fast and very fast). Results show that the representative household has a high marginal willingness to pay (WTP) for a high speed internet service, but a low marginal WTP for a very high speed service: *"The representative household is willing to pay $20 per month for more reliable service, $45 for an improvement in speed from 'slow' to 'fast', and $48 for an improvement in speed from 'slow' to 'very fast'."* This implies that the a representative household is willing to pay a relatively higher premium for an upgrade of broadband speed from a "slow" service to a "fast" broadband service, but only a small additional premium of US$ 3 per month for an upgrading from fast to a 'very fast' service.

A recent study[12] based on data from a web-based survey of 3600 respondents in the Netherlands in year 2010 showed that having a fibre connections that leads to symmetric upload and download speeds appear to have limited appeal given current bandwidth demand, and enjoy only a limited price premium of around 8%-15%, or around €5 in absolute terms.

[12] See Frans van Camp: *"FTTH Moves The Market",* XS Insight presentation at FTTH Conference 2012, Munich, February 15.

Similarly, a document of the German regulator (*Bundesnetzagentur*)[13] in 2011 reports that customers are prepared to spend around € 5/month for greater bandwidth. My personal informal request to the Italian incumbent operator, Telecom Italia, almost confirms this result; they claim that the incremental WTP of a representative Italian consumer for switching to fibre lies in the range of €4 – 6/month.

This premium for fibre is considered to be relatively modest – at least in the EU scenario - with respect to what is needed to spur consumers' migration from copper to fibre infrastructure. A document by WIK-Consult (2011)[14], prepared for ECTA i.e. the Association of entrant telecom operator in Europe, show that in the case where access price differentials are reflected in retail price differentials, an access charge gap that provides an incentive for fibre investment is only sustainable if the fibre premium, i.e. consumer's WTP, is above around € 8/month. A smaller fibre premium would require a difference in access prices that is greater than the retail price difference that end-users would be prepared to pay as reported in the following table:

	Difference in ARPU (fibre ARPU above copper ARPU)	Difference in access charges required to make fibre investment profitable
High copper (low fibre premium)	3.99	8.79
Medium copper (medium fibre premium)	7.97	7.86
Low copper (high fibre premium)	11.95	5.37

Source: WIK-Consult, "Wholesale pricing, NGA take-up and competition", prepared for ECTA, 7 April 2011.

Evidence from New Zealand provides further insights. In the Colmar Brunton report (2012)[15], prepared on the behalf off Chorus, and mentioned in the report by Prof. Vogelsang (2013; point 47), the WTP for UFB for 23% of consumers is at least

[13] "NGA Forum Report", November 2011.
[14] WIK-Consult, "Wholesale pricing, NGA take-up and competition", prepared for ECTA, 7 April 2011
[15] Colmar Brunton report, *Chorus consumer segmentation research – Paving the Path to Delivering Ultra Fast Broadband*, 2012. See: https://www.google.co.nz/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&ved=0CCEQFjAA&url=https%3A%2F%2Fwww.chorus.co.nz%2Ffile%2F50475%2FIntegrated-Fibre-Research-Chorus-Connections---Final-5th-Dec.pptx&ei=LDz2VMOpJqTcmAW3toC4BA&usg=AFQjCNE5GjYZ1xCvUc7V02PfSnbRcJW_cA&bvm=bv.87269000,d.dGY

NZ$20/month higher than for DSL, and 26% lower than NZ$20/month. On average the estimated WTP is NZ$20.70/month. These values slightly increase for Home Business, whose WTP ranges between NZ$22.10/month and NZ$25.10/month.

The Commerce Commission also conducted its own demand side study[16] on WTP for fibre services. The Commission found that only 4% of respondents were willing to pay more than NZ$20/month and that most respondents were willing to pay between NZ$5-10/month. However, the study also revealed that retailers expect a WTP difference of NZ$19/month and that the speed requirements for services are increasing rapidly so that higher WTP differences can be expected in the next few years.

[16] http://www.comcom.govt.nz/regulated-industries/telecommunications/monitoring-reports-and-studies/studies/

APPENDIX

The economics of migration to fibre and its focus on investment incentives

The new investments in fibre will not immediately replace the copper or cable legacy networks, suggesting that the transition from old infrastructures to new infrastructures will go slowly. Replacement will be gradual for several reasons, such as: {i} the regulatory constraints on copper networks, which rule out an immediate switch-off of the old network; {ii} the uncertainties about demand and investment costs, which call for a progressive investment strategy; and {iii} the financial market constraints that imply that roll-out must be phased.

This implies that, during a transition phase, two different infrastructures will operate, and presumably each type of network will be regulated with a different set of rules. The incentives to invest in fibre infrastructures will therefore be influenced not only by the terms of access set for fibre infrastructures, but also by the terms of access set for the legacy copper networks. The recent economic literature has therefore focused on how access regulations on the existing old network affect infrastructure investments in new networks.

Recent literature has developed around the relationship between access pricing and investment incentives. Brito et al. (2012) assume that the new technology is not subject to regulation, and analyze the regulator's decision depending on whether the innovation is drastic or non-drastic. In the presence of a non-drastic innovation (such as Ethernet connectivity, 4G mobile networks and NGAN, at least in the short run), monopolization of the industry is not a concern, and hence, the regulator can increase the entrants' competitiveness by setting a low access charge on the copper network and let them compete fiercely with the incumbent. On the other hand, if innovation is drastic in nature, the incumbent can monopolize the market, and therefore the regulator should introduce specific incentives for entrant operators to invest in alternative infrastructures.

The first systematic analysis of migration is provided by Bourreau, Cambini and Dogan (2012).[17] The authors consider a model where access to the legacy copper network (in the form of local loop unbundling) is available everywhere in a country, and an incumbent and an entrant operator compete for the provision of retail broadband services to consumers.

In their setting, the country is composed of a continuum of areas, for which the fixed cost of a new network varies. Hence, the authors assume the presence of a variety of different regional markets. Firms decide sequentially on their investments in fibre networks in the different regional markets, with the incumbent firm as the first mover, due to its control over the legacy network and over other essential facilities such as ducts. However, the incumbent's investment generates positive spillovers: the entrant's fixed cost of investing in a new network is assumed to be lower in the areas where the incumbent has already rolled out its fibre infrastructure than in those areas where a fibre network is absent.[18] Access to the legacy network is regulated; the fibre network is left totally unregulated.

In the competition stage, three conflicting effects emerge in this setting:

> {i} when the access charge for the existing infrastructure is set at a high level, the entrant's opportunity cost of investment is low, which promotes infrastructure investment by the alternative operator; this corresponds to the so-called *replacement effect*;
>
> {ii} a higher access charge increases the incumbent's opportunity cost of investment due to the *wholesale revenue effect*: if the incumbent invests in a higher quality network, the entrant will invest in reaction, and the incumbent will then lose some wholesale profits;
>
> {iii} when the access charge on the legacy network is low, the prices for the services which rely on this network are low, hence, in order to encourage customers to

[17] See also Bourreau et al. (2014).

[18] For example, when the incumbent builds a fibre network in a given area, it may have to obtain administrative authorizations, gather information on existing ducts or rights of passage, etc., which generates administrative and contractual costs. When the entrant decides to roll out its own NGA network in the same area, its investment costs are lower if it benefits from the incumbent's earlier efforts. Other potential reasons could be informational spillovers as well as direct cost savings due to infrastructure sharing.

switch away from the legacy network, operators would need to make low-priced fibre offers. This latter effect, which is referred to by the authors as the *retail migration effect*, reduces the profitability of the new infrastructure, and hence, the incentives to invest in it.[19]

The coexistence of these multiple effects creates a non-monotonic relation between the access price for copper and the investments in the new access technology (i.e., the coverage of the fibre networks).

From a social point of view, there can be conflicts between different potential objectives:

{i} a higher access charge on the legacy network stimulates investment by entrants (if alternative operators are expected to invest in fibre) and sometimes (but not always) by incumbents, enhancing dynamic efficiency;

{ii} however, a higher access charge negatively affects static efficiency due to higher retail prices in uncovered areas, and duplication of fixed costs.

Using simulations,[20] the authors show that the socially optimal access charge to the legacy network depends on the degree of investment spillovers: If the degree of spillovers is relatively small, the regulator should set the legacy access price at marginal cost; conversely, when spillovers are strong, the access charge should increase proportionally with spillovers. Intuitively, if the entrant can obtain a considerable reduction in its investment cost due to the spillover from the incumbent's investment, then the regulator should raise the access charge to the legacy network in order to favor investment. The idea is that, when there are strong spillovers, the incumbent's investment stimulates the entrant's investment. To avoid

[19] The business migration effect plays a role in the short term, as long as the migration towards fibre networks takes time. Obviously, it is absent if the regulator or the incumbent can force the entrants to switch very fast to fibre networks.

[20] These simulations are present in the working paper version of the paper (Bourreau et al, 2011).

losing wholesale revenues, the incumbent has incentives to reduce its fibre investment. In this case, the entrant does not invest much either, as it faces high investment costs. This is why the regulator should increase the access price on the legacy network in order to provide both firms with stronger investment incentives to invest and counter balance the spillover effect.

Inderst and Peitz (2012) also consider the migration issue. The authors investigate the incentives to invest in a new technology when one of the firms is the owner of an old technology, and focus on the case where investment costs are too high relative to demand to make network expansion profitable for more than one of the two firms. More specifically, the authors focus on so-called "brownfield investments" which are characterized by an asymmetry between the incumbent using the old legacy network and his competitor, which has to choose between using the existing infrastructure and investing in a new high-speed infrastructure. Inderst and Peitz find that, when regulated access fee for the legacy network is high, the incumbent firm has low incentives to invest. However, the competitor, who has no access network at the beginning, has stronger incentives to invest in a fibre infrastructure. This is especially true when it is possible to sign a contract on a commercial basis that fix the terms of usage for the new access network. These results are similar to the ones derived by Bourreau et al. (2012), but in a more simplistic model with only one type of area.

To sum up, all the papers stress that the incentives to invest in fibre infrastructures differ between the historical operators and the new entrants. Incumbents may invest more in a new infrastructure when the access price to the old network is raised but this in turn could also deprive incentives if wholesale copper services become too remunerative. On the contrary, entrants may speed up the deployment of new infrastructures when access charge to copper is high, but only if they are required to invest in fibre networks.

References

Bohlin E. (2012), "The Mobile and Fixed Broadband Battle in Sweden". Prepared for the International Conference on Mobile broadband-Competitive dynamics and policy implications, Bruxelles, September.

Bouckaert, J., Van Dijk, T., & Verboven, F. (2010). Access regulation, competition, and broadband penetration: An international study. *Telecommunications Policy*, 34(11), 661–671.

Bourreau, M., Cambini, C., & Doğan, P. (2011). "Access Pricing, Competition, and Incentives to Migrate from "Old" to "New" Technology." Harvard Kennedy School of Government, Working Paper No. 11-029, July, Cambridge (MA).

Bourreau, M., Cambini, C., & Doğan, P. (2012). "Access Pricing, Competition, and Incentives to Migrate from "Old" to "New" Technology." *International Journal of Industrial Organization*, 30(6), 713-723.

Bourreau, M., Cambini, C., & Doğan, P. (2014). "Access Regulation and the Transition from Copper to Fibre Networks in Telecoms." *Journal of Regulatory Economics*, 45(3), 233-258.

Briglauer, W. (2014), "The Impact of Regulation and Competition on the Adoption of Fibre-Based Broadband Services: Recent Evidence from the European Union Member States", *Journal of Regulatory Economics*, 46(1), 51-79.

Brito, D., Pereira, P., & Vareda, J. (2012). "Incentives to Invest and to Give Access to New Technologies.", *Information Economics and Policy*, 3-4, 197-211.

Cave, M., & Vogelsang, I. (2003). How access pricing and entry interact. *Telecommunications Policy,* 27, 717-727.

Cave, M. (2010), Snakes and ladders: unbundling in a next generation world, *Telecommunications Policy*, 34, 80-85.

Czernich, N., Falck, O., Kretschmer, T. & Woessmann, L. (2011). Broadband Infrastructure and Economic Growth. *The Economic Journal*, 121, 505--532.

Duts, M., J. Orszag & R. Willig (2009), "The Substantial Consumer Benefit of Broadband Connectivity for US Households".

Grajek, M., & Kretschmer, T. (2009). Usage and diffusion of cellular telephony, 1998-2004. *International Journal of Industrial Organization*, 27, 238-249.

Grajek, M., & Roller, L. (2012). "The effect of regulation on investment in network industries: evidence from the telecommunications industry." *Journal of Law and Economics*.

Greenstein, S., & McDevitt, P. (2009). The Broadband Bonus: Accounting for Broadband Internet's Impact on US GDP. *NBER Working Paper* no. 14758, Cambridge, MA.

Grzybowski L., Nitsche R., F. Verboven & L. Wiethaus (2014), "Market Definition for Broadband Internet in Slovakia. Are Fixed and Mobile Technologies in the Same Market?", *miemo*.

Inderst, R., & Peitz, M. (2012). "Market Asymmetries and Investments in NGA." *Review of Network Economics*, 11(1), article 2.

Lee, S., & Lee, S. (2010). An empirical study of broadband diffusion and bandwidth capacity in OECD countries. *Communications & Convergence Review*, 2(1). KISDI.

Koutroumpis, P. (2009). The Economic Impact of Broadband on Growth: A Simultaneous Approach. *Telecommunication Policy*, 9, 471-485.

Rosston, G.L., Scott J. Savage, & Donald M. Waldman (2010) "Household Demand for Broadband Internet in 2010," *The B.E. Journal of Economic Analysis & Policy*: Vol. 10: Issue 1, Article 79. Available at: http://www.bepress.com/bejeap/vol10/iss1/art79.

Shinohara, S., Akebatsu, Y., and M. Tsuji, "Analysis of broadband services diffusion in OECD 30 countries: Focusing on open access obligations", paper given at 8th ITS Asia-Pacific Regional Conference, Taiwan, June 26-28, 2011. Available at http://hdl.handle.net/10419/52312.

SQW (2008), *Broadband in the Home: An Analysis oft he Financial Costs and Benefits*. London.

Srinuan P., Srinuan C. & E. Bohlin (2012),"Fixed and Mobile Broadband Substitution in Sweden", *Telecommunications Policy*, 36, 237-251.

Vogelsang, I. (2013), "What effect would different price point choices have on achieving the objectives mentioned in s 18, the promotion of competition for the long-term benefit of end-users, the efficiencies in the sector, and incentives to innovate that exist for, and the risks faced by investors in new telecommunications services that involve significant capital investment and that offer capabilities not available from established services?", *Paper prepared for the New Zealand Commerce Commission*, 5 July 2013.

Waverman, L., Meschi, M., Reillier, B., & Dasgupta, K. (2007). *Access regulation and infrastructure investment in the telecommunications sector: an empirical investigation*. Report by LECG Consulting, London, UK. Available at: http://www.etno.be/Portals/34/ETNO_Documents/LECG_Final_Report.pdf