Economic value of the take-up of ultra-fast broadband in New Zealand

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Executive summary

This is an independent report contributing further information and analysis on the potential benefits of ultra-fast broadband (UFB) to New Zealand. UFB uses optical fibre technology rather than the slower copper-based technologies. Chorus offers a mass market product with a minimum speed of 100 Mbps downstream (from the Internet to the user) and a minimum of 20 Mbps upstream (from user to the Internet), and products with faster upstream services to businesses. Our report starts with a "bottom-up" assessment of potential gains in labour productivity as a result of the faster speeds associated with a fibre connection. We then translate those gains to more macro-levels impacts on the New Zealand economy. Chorus New Zealand Limited provided funding and factual data to inform this report.

We find that employees in firms with a fibre connection had, on average, value added levels that were 29% higher than employees in firms without a fibre connection. Translating this firm-level impact to the national economy, we estimate that an additional 10% of employees gaining access to UFB in the workplace would result in a gain of 1.62% of gross domestic product (GDP). This is a substantial impact in the context of New Zealand's annual growth in GDP, which has ranged from 1.4% to 3.6% in the year to March, over 2011 to 2016.

In dollar terms, this result equates to almost $3.3 billion. As a comparison, the contribution to GDP from the Forestry and Logging industry in the year to March 2015 was $1.4 billion, while the combined contribution to GDP of the Textile, Leather, Clothing and Footwear Manufacturing, Wood and Paper Products Manufacturing and Printing industries was around $3.3 billion. This result is also larger than the individual contribution to annual GDP of three of the 15 regional jurisdictions in New Zealand (West Coast, Gisborne and Marlborough).

This work is novel in two ways. Firstly, it utilises firm-level data from official surveys – to which firms are statutorily obliged to respond. This improves the representativeness and authenticity of the data, relative to non-official methods. Secondly, this work translates firm-level findings to economy-wide impacts using well understood economic aggregates (i.e. contribution to GDP). This 'bottom-up' approach differs from most published studies, which tend to rely on 'top down' methods using aggregated economic data.

We do stress however, that while the study is a pragmatic means of exploiting valuable firm-level data, it is somewhat limited in terms of being able to establish causality. That is, factors other than fibre uptake that might influence labour productivity are not able to be controlled for. In light of this, we compare our result against research that has attempted to use statistical methods to isolate the effect in question from other influences.

Our result is broadly in line with those other estimates of the economic gain from broadband uptake in general and the more limited evidence on the impact of faster broadband speed. In particular, we find that our result of a 1.62% contribution to GDP from an additional 10% of employees gaining access to UFB is around the midpoint of the feasible range of 1.29% and 2.13% of GDP – obtained by adapting the modelling of Kongaut and Bohlin (2014) with respect to broadband speed in high and low-income OECD countries. This appears reasonable, given that New Zealand's income per capita is mid-range within the OECD.

In summary, we find New Zealand-specific support for the proposition that there are likely to be material gains from further uptake of ultra-fast broadband by New Zealand firms. The magnitude of overall gains from higher UFB uptake could be enhanced with the inclusion of measures of societal well-being that are not considered in this report.

Purpose and approach

Purpose of this report

1. This report quantifies the impact on the New Zealand economy from the take-up of ultra-fast broadband (UFB). The particular representation of UFB used in this analysis is the uptake by businesses of a fibre broadband connection. This report presents our findings with respect to the economic gains, in the form of gross domestic product (GDP), from an additional 10% of employees gaining access to UFB in the workplace.

Our approach to this work

2. This work is novel in two main ways. Firstly, it utilises firm-level data from official surveys – to which firms are statutorily obliged to respond. This improves the representativeness and authenticity of the data, relative to non-official methods. Secondly, this work translates firm-level findings to economy-wide impacts using well understood economic aggregates (i.e. contribution to GDP). This 'bottom-up' approach differs from most published studies, which tend to rely on 'top down' methods using aggregated economic data.

3. We begin with primary research based on New Zealand data. Our method for estimating the economic impact from higher take-up among firms is pragmatic, given the constraints of available data and the purpose of this work. Data relevant to UFB uptake is sourced from the Business Operations Survey (BOS), an annual survey conducted by Statistics New Zealand with a sample of nearly 7,000 "economically significant" businesses.[1] The BOS includes a separate ICT component every two years, which has relevant questions on firm connectivity, such as the type of connectivity, reasons for connectivity and relevant uses.

4. Data on firm revenue and costs is provided by the Annual Enterprise Survey (AES), which is also administered by Statistics New Zealand. We draw on a cross-tabulation of data from these two surveys to determine whether firms "with a fibre connection" (as a proxy for UFB) differ from those without a fibre connection, in terms of estimated labour productivity.

5. We examine data on average labour productivity – in the form of value added per worker – for firms that use a fibre connection with those firms that do not. Value added is derived from firm-level revenue less the cost of goods and services used in the production process (including capital and labour inputs). We then model the

1 The target population for the Business Operations Survey comprises private, live enterprises that are economically significant (annual expenses or sales subject to GST of more than $30,000), have six or more employees, and have been operating for one year or more.

labour productivity impact on GDP from additional 10% of employees gaining access to UFB in the workplace.[2]

6. Our approach is valuable in terms of unearthing findings that may previously have remained implicit and being essentially data-driven as opposed to assumption-driven. Nevertheless, the scarcity of directly comparable approaches and evidence means that the results of this work are a platform to work from – rather than the final word on this topic. For that reason, we subject our results to some scrutiny in terms of comparisons with existing and emerging literature.

7. This stage involved undertaking an Internet-based search for published research on the economic impacts of broadband uptake and of changes in broadband speed, including prior work in the New Zealand context. We draw on values identified in the available research to establish a plausible range as context for our own result.

2 See the appendix for further detail on the estimation method.

Context – definitions and take-up

Broadband definitions

8. Broadband is defined by the International Telecommunications Union as a service which provides transmission capacity in excess of 2.0 Megabits per second (Mbps). High-speed broadband, which for the purposes of the New Zealand government initiative is termed as UFB, uses optical fibre technology rather than the slower copper-based technologies.[3] Chorus offers a mass market residential UFB product of broadband services at a minimum speed of 100 Mbps downstream (from the Internet to the user) and a minimum of 20 Mbps upstream (with some 30/10 plans, and offers some faster upstream services to businesses.

Uptake of ultra-fast broadband

9. Fixed-lined broadband is a mature technology in the majority of OECD countries. The most significant prospective development is now the deployment and adoption of newer forms of access in the form of mobile broadband and ultra-fast networks delivering speeds of 100 Mbps or more.[4] According to the OECD Broadband Portal, the number of fibre connections to the home/premise/building reached 17.9% of fixed broadband subscriptions, on average across the OECD in 2015. Figure 1 shows that the equivalent figure for New Zealand was 7.5%.

10. In contrast, the rate of growth in fibre connections to New Zealand firms and households has been among the highest in the OECD – reflecting investment in UFB infrastructure. Figure 2 shows that the increase for New Zealand was 124% in the year to June 2015 whereas average growth among the OECD countries that reported data was 14%.

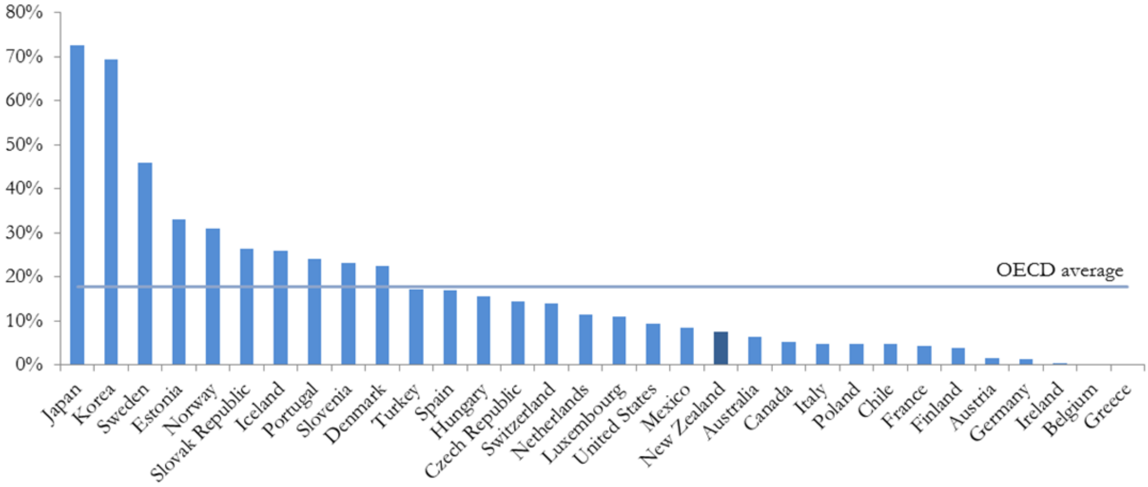
11. In terms of New Zealand firms, data from the 2014 BOS show that 95% of firms used broadband in some form and 22% of firms were connecting using fibre.[5] The data shows that firms using fibre accounted for approximately 69% of employees – as larger firms are more likely to connect via fibre than small firms. The data also shows that firms with a fibre connection had, on average, 220 employees whereas firms that did not connect with fibre had an average of 60 employees.

[3] Copper-based technology includes ADLS (Asymmetric digital subscriber line) VDSL (Very-high-bit-rate digital subscriber line) communications technologies.

[4] OECD (2014), "The Development of Fixed Broadband Networks", *OECD Digital Economy Papers*, No. 239

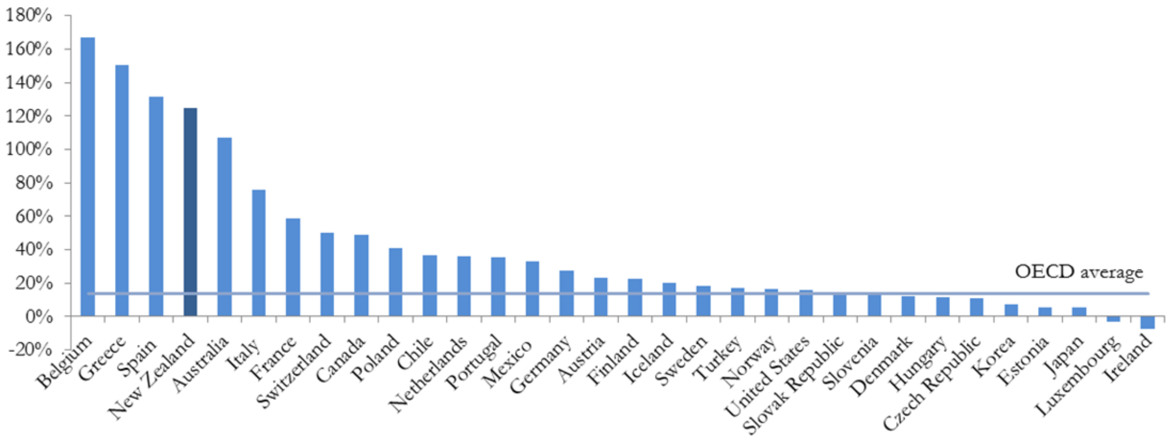
[5] Statistics New Zealand (2010, 2012 and 2014) Business Operations Survey; published tables

Figure 1: Fibre connections in total broadband subscriptions, by OECD country, 2015



Source: OECD Broadband Portal, 2015

Figure 2: Annual growth of fibre subscriptions, by OECD country, June 2014-2015



Source: OECD Broadband Portal, 2015

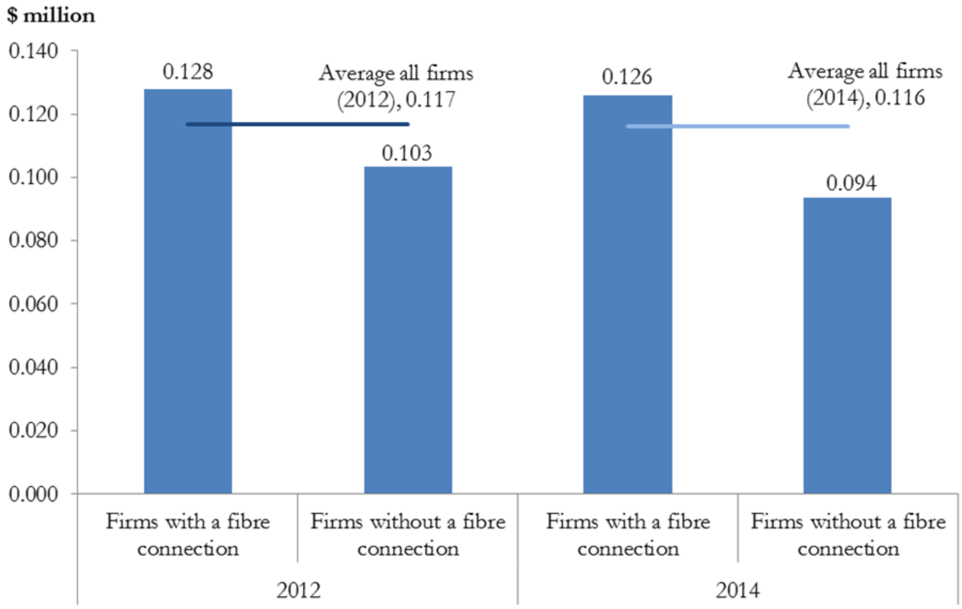
Estimating the value of higher UFB uptake in New Zealand

Labour productivity among firms using fibre

12. Drawing on matched data from the Business Operations Survey and the Annual Enterprise Survey, we examine average labour productivity – in the form of value added per worker for firms that use a fibre connection and those that do not. Value added is derived from firm-level revenue less the cost of goods and services used in the production process (including capital and labour inputs).

13. Figure 3 shows that firms that connect with fibre tend to have higher labour productivity than those that do not. In 2012, firms that used a fibre connection had, on average, value added of $0.128 million per worker – 23.5% higher than the average of $0.103 million per worker for firms that did not use a fibre connection.[6] Similarly, in 2014, firms using a fibre connection had, on average, value added of $0.126 million per worker – 34.4% higher than the average of $0.094 million for firms not using a fibre connection. Across 2012 and 2014, value added per worker was, on average, 29.0% higher among firms using a fibre connection.

Figure 3: Average value added per worker among firms, 2012 and 2014



Source: Statistics NZ, BOS (2012, 2014) and AES (2012, 2013); author calculations

6 The measure of workers in the data is RME – rolling mean employment figures

14. It must be noted that fibre broadband is not necessarily wholly responsible for the higher labour productivity observed among firms using a fibre connection. Firms using fibre may already tend to be more productive for other reasons. It is also plausible that these firms have, in the main, made rational choices about adopting fibre – for the cases where gains to their production processes and profits exist.

15. Counter to these points, it is plausible that some firms have not had an opportunity to connect to the UFB network or they remain unaware of any potential benefits. In addition, established conventions or inherent conservatism may mean some sectors tend to be slow movers or late adopters (e.g. agriculture and parts of manufacturing). To the extent that the economic gains from UFB in these untapped sectors are sizeable – which, for instance, may well be the case for pastoral farming – then we might reasonably expect commensurate gains from higher uptake of UFB.

16. If we assume, for the moment, that this observed higher labour productivity is due to the presence of a fibre connection then it is of interest to consider what might an increase in UFB uptake among New Zealand firms mean for economic output.[7] We address this issue in the next section.

Translating possible firm-level impacts to the wider economy

17. We consider how the higher labour productivity associated with the use of fibre connections at the level of the firm might be translated to a macroeconomic level. That is, how an increase in productivity per worker impacts on GDP.

18. In terms of the economy as a whole, our core assumption is that fibre broadband enhances the productivity of labour – as opposed to the productivity of capital. Simply, a worker who gains access to ultra-fast broadband will produce more output per hour worked because they will become more efficient. As an example, an analyst in a financial trading firm may be able to make more transactions per hour in the presence of a faster connection. Alternatively, ultra-fast broadband may allow the use of more real-time data which may streamline a supply-chain and save time. In these examples, the impact is higher throughput for the same number of workers.

19. The GDP of an economy can be thought of as being determined by four factors: its capital stock, the hours worked by its labour force and the productivity of its capital and its labour. Further a one percent increase in labour input (either through an extra hour worked or through the labour force becoming more productive) will have a different effect on GDP as a one percent increase in capital. We estimate that a one percent increase in productivity per worker leads to 0.56 percentage point increase in New Zealand's GDP. The rationale for using this value is outlined in Appendix 1.

[7] Note that the focus of our work is on results across the entire economy, rather than specific sectors. Previous work has shown there is considerable volatility in the data both across and within industry sectors and the use of other techniques (e.g. case studies) is more helpful in understanding that variation.

Key result with respect to a 10% increase in UFB uptake

20. We consider the effect on GDP of an additional 10% of employees gaining access to ultra-fast broadband. We do this by calculating the product of three factors:

- the average firm-level labour productivity differential associated with a fibre connection across 2012-2014 (i.e. 29%);
- the estimated elasticity of output to effective labour (i.e. 0.56); and
- the change in UFB uptake among employees (i.e. +10 percentage points).

21. We obtain a result of 1.62% – which represents our estimated increase in GDP from an additional 10% of employees gaining access to ultra-fast broadband at work. In terms of firms, we estimate that this increase in employees would entail an additional 20% of firms connecting via ultra-fast broadband – given that firms that do not currently have a fibre connection tend to have fewer employees than those that do.

Placing this result in context

22. It is useful to place this estimate in context, both to make it seem tangible but also as a form of validation. For instance, our point estimate of 1.62% of GDP equates to around $3.3 billion of total annual GDP for the year to March 2015.[8] This estimate is larger than the contribution of the Arts and Recreation Services industry (which includes performing arts, sporting activities and gambling) in the March 2015 year.

23. Further, the contribution to GDP from the Forestry and Logging industry in the year to March 2015 was $1.4 billion, while the combined contribution to GDP of the Textile, Leather, Clothing and Footwear Manufacturing, Wood and Paper Products Manufacturing and Printing industries approximates $3.3 billion. This estimate is also larger than the GDP contributions of West Coast, Gisborne and Marlborough.[9]

24. Looking at this estimate from another perspective, New Zealand's annual growth in GDP has ranged between 1.4% and 3.6% in the year to March, over the period 2011 to 2016.[10] In this context, a gain in GDP of 1.62% would be a substantial impact.

Testing the reasonableness of our result

25. We draw on the results from Kongaut and Bohlin (2014) to as a high-level test for the reasonableness of our result.[11] Kongaut and Bohlin used OECD data to develop a series of econometric models that show that broadband speed contributes positively to GDP.

8 Figures are expressed in 2009/10 prices. Total GDP for the March 2015 year was $203,633 million. Table SNE066AA retrieved from Statistics New Zealand website

9 These figures are expressed in current prices.

10 Statistics New Zealand (2016) Gross Domestic Product: March 2016 quarter; Table 6 http://www.stats.govt.nz/browse_for_stats/economic_indicators/GDP/info-releases.aspx

11 Kongaut, C. and Bohlin, E. (2014) "Impact of broadband speed on economic outputs: An empirical study of OECD countries."

26. They offer three preferred models, differentiated by scope – i.e. all OECD countries, low-income OECD countries and high-income OECD countries. In each case, the results are portrayed as a gain in average broadband speed of *x%* yielding a GDP gain of *y%*. We adapt these results to a New Zealand context via the following steps.

(a) We asked Chorus to model the impact on average broadband speed if an additional 20% of firms connected to UFB business packages – representing an additional 10% of employees gaining access to UFB in the workplace. The result is an estimated increase in average broadband speed of 22%.[12]

(b) This change in speed is multiplied by the relevant co-efficient in each of the three preferred models to give three estimated impacts on GDP:

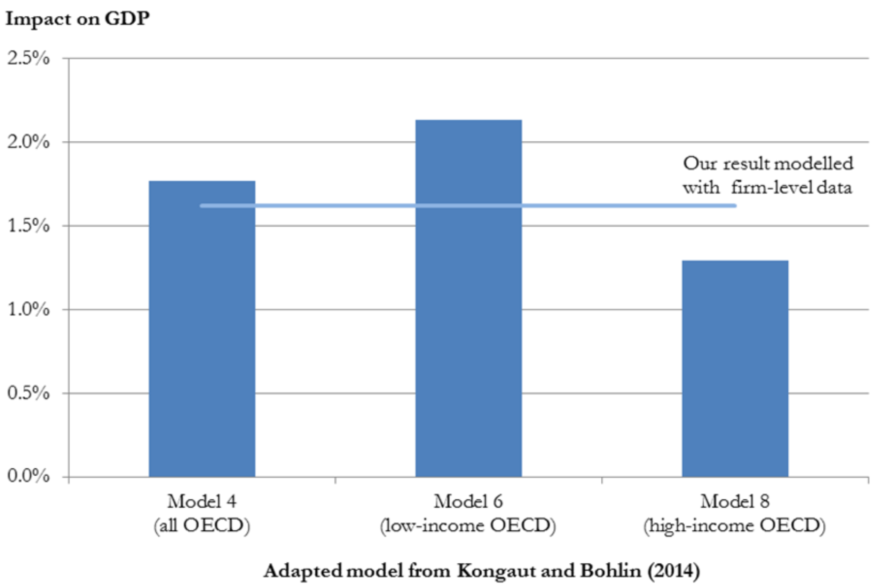
(i) Model 4 (all OECD countries) has a co-efficient of 0.0807 for each 1% gain in average speed, therefore 22% * 0.0807 = 1.77%;

(ii) Model 6 (low-income OECD countries) has a co-efficient of 0.0975 for each 1% gain in average speed, therefore 22% * 0.0591 = 2.13%; and

(iii) Model 8 (high-income OECD countries) has a co-efficient of 0.0591 for each 1% gain in average speed, therefore 22% * 0.0591 = 1.29%.

27. Figure 4 shows that our result of 1.62% of GDP sits within the range derived from this high-level adaption of the Kongaut and Bohlin models. This appears reasonable, given that New Zealand's income per capita is mid-range among OECD countries.

Figure 4: Modelled impact of an additional 10% of employees accessing UFB



Source: author calculations; Kongaut and Bohlin (2014)

12 This equates to 88,000 firms of the 438,000 economically significant firms in Statistics New Zealand's survey population. The modelled change in broadband speed uses the speed forecast for December 2016 as a base.

Placing our result within the literature

Broadband and economic growth

28. Most research considers the impact of broadband uptake rather than focusing on the issue of ultra-fast speeds. A paper by the ITU in 2012 summarises the research at that time, reproduced here in Table 1. It finds that most studies conclude that broadband penetration has an impact on GDP growth, although the findings vary widely, from 0.25% to 1.38% for every 10% increase in broadband penetration.[13]

29. This research involves a range of sophisticated econometric techniques, which examine the relationship between broadband uptake and economic performance across a range of countries over a period of time. In doing so, they hold constant the effects of other influencing factors. Therefore, the variation in these results can be a due to the approach (i.e. mix of countries, time period) as much as degree of uptake.

Table 1: Results of research into broadband impact of GDP growth

Countries included	Authors / institution	Data	Effect from a 10% increase in broadband uptake
United States	Crandall *et al.* (2007) – Brookings Institution	48 states of US for the period 2003-05	Not statistically significant
	Thompson and Garbacz 92008) – Ohio University	46 states during the period 2001-2005	Associated with 3.6% increase in efficiency
OECD	Czernich *et al.* (2009) University of Munich	25 OECD countries during 1996-2007	Raises GDP growth per capita by 0.9-1.5 percentage points
	Koutroumpis (2009) – Imperial College	22 OECD countries during 2002-2007	Yields a 0.25% increase in GDP growth
High income economies	Qiang *et al* (2009) – World Bank	66 high income countries during 1980-2002	Yields a 1.21% increase in GDP growth
Low & middle income economies	Qiang *et al* (2009) – World Bank	120 low-middle income countries during 1980-2002	Yields a 1.38% increase in GDP growth

Source: ITU (2012)

[13] ITU (2012) "The impact of broadband on the economy: research to date and policy issues" *Broadband series*

30. The ITU also paper identifies three main ways or channels through which the uptake of broadband contributes to economic growth.

(a) Firstly, the deployment of broadband technology across business enterprises improves productivity by enabling more efficient business processes (e.g., marketing, inventory optimisation, and streamlining of supply chains).

(b) Secondly, extensive deployment of broadband accelerates innovation by introducing new consumer applications and services (e.g., new forms of commerce and financial intermediation).

(c) Thirdly, broadband leads to a more efficient functional deployment of enterprises by maximizing their reach to labour pools, access to raw materials, and consumers, (e.g., outsourcing of services, virtual call centres.)

31. Some caution is required about whether there is a linear relationship between broadband adoption and economic growth. The ITU concludes that the "critical mass" of research finding indicates that the impact of broadband on economic growth may only become significant once the adoption of the platform achieves high penetration levels. The ITU notes that, conversely, Gillett et al. (2006) contend that the relation between penetration and economic impact should not be linear "because broadband will be adopted (...) first by those who get the greatest benefit (while) late adopters (...) will realize a lesser benefit".[14]

Impact of high-speed broadband

32. While speed is implicit in the studies involving broadband uptake, there has been a relatively limited amount of research looking explicitly at the economic impact of faster broadband speeds. To some extent this reflects the complex interplay between speed and uptake, as well as the understanding that speed is only one component in broadband choice, alongside other factors such as quality of service and reputation of service providers.

33. As indicated above, Kongaut and Bohlin (2014) find that "…broadband speed contributes positively to economic outputs such as GDP. The effects of broadband speed are also greater in countries with lower income."[15] The authors note that these findings are consistent with previous studies related to broadband speed (Katz et al., 2010, Rohman and Bohlin, 2012, and Forzati and Mattsson, 2012).

34. On the other hand, a New Zealand study by Grimes et al (2009) found that broadband adoption boosts productivity but was unable to detect a productivity effect from broadband type (as a proxy for speed). They offer several reasons why this might be so, including:

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14 Gillett, S., Lehr, W., and Osorio, C., & Sirbu, M. A. (2006). Measuring Broadband's Economic Impact. *Technical Report 99-07-13829*, National Technical Assistance, Training, Research, and Evaluation Project

15 Kongaut and Bohlin (2014), p.1

- errors in the measurement of broadband speeds (e.g. the classification of broadband connection types may be a poor proxy for speed, and some survey respondents may not have been aware of their connection type);
- initiation bias – firms that have only recently adopted faster broadband are yet to achieve the full productivity benefits. This may be relevant because the data used in the study dated from 2006; and
- the productivity benefits of adopting fast broadband may only have been relevant to a small proportion of firms, at that time, and so the full future benefits may not be apparent in the existing data.

35. We are aware that this study is being updated at present. Table 2 provides a summary of the results of these studies.

Table 2: Results of research into economic impacts of high speed broadband

Authors / institution	Countries	Data	Effect
Grimes *et al* (2009)	New Zealand	BOS data for 2006	No significant effect
Rohman and Bohlin (2012)	OECD	33 OECD countries during the period 2008-2010	Doubling the speed encourages 0.3% GDP growth, on average
Kongaut and Bohlin (2014)	OECD	Model 4: all OECD countries	A 10% increase in broadband speed yields a 0.80% increase in GDP per capita
		Model 6: low-income OECD countries	A 10% increase in broadband speed yields a 0.97% increase in GDP per capita
		Model 8: high-income OECD countries	A 10% increase in broadband speed yields a 0.59% increase in GDP per capita

Source: Kongaut and Bohlin (2014)

Concluding remarks

36. We find New Zealand-specific support for the proposition that there are likely to be material gains from further uptake of ultra-fast broadband by New Zealand firms. The key result here is that an additional 10% of employees gaining access to UFB in the workplace would lead to an estimated increase in GDP of 1.62%. This is a substantial impact in the context of New Zealand's annual growth in GDP, which has ranged from 1.4% to 3.6% in the year to March, over the period 2011 to 2016.

37. We do stress however, that while this study is a pragmatic means of exploiting valuable firm-level data, it is somewhat limited in terms of being able to establish causality. That is, factors other than fibre uptake, which might also influence labour productivity, are not able to be controlled for. In light of this, we compare our result against research that has attempted to use statistical methods to isolate the effect in question from other influences.

38. Our result is broadly in line with those other estimates of the economic gain from broadband uptake in general and the more limited evidence on the impact of faster broadband speed. In particular, the comparison of our result of a 1.62% gain in GDP with the feasible range of 1.29% and 2.13% of GDP – obtained by adapting the work of Kongaut and Bohlin for high and low-income OECD countries – seems reasonable, given that New Zealand's income per capita is mid-range among OECD countries.

39. For completeness, we note that this finding does not include any wider benefits that may arise from the increased take up of ultra-fast broadband among firms, such as increases in consumer surplus from efficiency gains being translated into lower prices or from new products becoming available. Finally, we note that the focus here has been on businesses and so any wider societal gains in wellbeing from the increased take-up of ultra-fast broadband – e.g. those being obtained by government, NGOs and households – have not been explored.

References

Conway, P., Meehan, L., & Parham, D. (2015) "Who benefits from productivity growth? – The labour income share in New Zealand", *New Zealand Productivity Commission Working Paper 2015/1*. Wellington: Productivity Commission

Grimes, A., C. Ren and P. Stevens (2009) "The Need for Speed: Impacts of Internet Connectivity on Firm Productivity" *Motu Working Paper 09-15* Motu Economic and Public Policy Research

ITU (2012) "The impact of broadband on the economy: research to date and policy issues" *Broadband series*. International Telecommunication Union; April 2012.

Kongaut, C. and Bohlin, E. (2014) "Impact of broadband speed on economic outputs: An empirical study of OECD countries", 25th European Regional Conference of the International Telecommunications Society (ITS), Brussels, Belgium, 22-25 June 2014

OECD (2014), "The Development of Fixed Broadband Networks", *OECD Digital Economy Papers*, No. 239, OECD Publishing.

Rohman, I. K. and Bohlin, E. (2012) "Does broadband speed really matter as a driver of economic growth? Investigating OECD countries". *International Journal of Management and Network Economics 5*, *2*(4), 336-356.

Appendix 1: Estimating the elasticity of output to effective labour

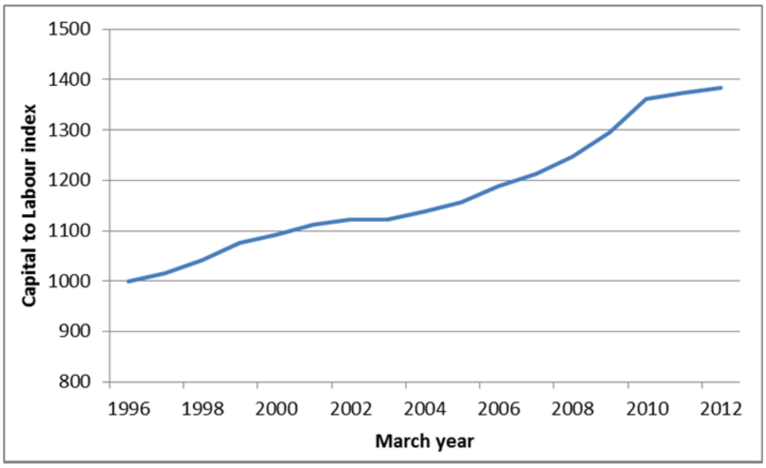
We seek to translate our estimate of the firm-level impact of UFB uptake into an economy wide impact (as measured by GDP). To do this, we begin with the well-known Cobb-Douglas production function.

$$Y = (AL)^{\alpha} (K)^{(1-\alpha)} \qquad (1)$$

Where Y is real GDP (i.e. GDP in constant dollar or volume terms), K is the capital stock, A is labour-augmenting productivity (specifically productivity per worker) and L is the aggregate number of hours paid in the economy. The AL part of the equation can be thought of as effective labour. Effective labour is the idea that labour's contribution to the economy can be enhanced through either increasing the amount of hours worked by workers (L) or increasing the productivity of each worker (A).

The above production function assumes labour-augmenting technological process. This means that technological innovation, such as UFB, makes labour more productive. Solow (1956) showed that a production function with labour-augmenting technological process implies the growth rate of the capital-to-labour ratio equals the rate of technological progress.[16] In other words, if technology is assumed to improve over time, it implies the capital-to-labour ratio should be increasing over time. The figure below shows the capital to labour ratio in New Zealand is indeed increasing over time. This leads us to conclude that the labour-augmented production function is a reasonable assumption in the New Zealand context.

Figure 5: Capital-to-Labour ratio in New Zealand, 1996 to 2012



Source: Statistics New Zealand

16 Solow, R. M. (1956). "A contribution to the theory of economic growth" in *The Quarterly Journal of Economics*, 65-94

The key parameter for us is the alpha term (or the elasticity of output to labour). This translates the change in labour productivity owing to UFB uptake into its effect on GDP. In a Cobb-Douglas specification of the production function (such as we have above), the elasticity of output to labour should equal labour's share of output (labour's income share) in the economy. Conway *et al.* (2015) report on the evolution of the labour income share (LIS) in New Zealand's measured sector, as follows.

> *The LIS has declined in the measured sector of the New Zealand economy since the late 1970s… Over the late 1970s to 2010, the LIS had a high of 65.9% in 1981 and a low of 53.9% in 2002. By 2010, the LIS was at 56.1%.*[17]

This implies an elasticity of labour or alpha of 0.56, which we adopt as an assumption for the purposes of our analysis. We therefore use the calculation $P * \alpha * \Delta U$ to estimate the increase in real GDP from an additional 10% of employees gaining access to an ultra-fast broadband connection – where:

- P is the average firm-level labour productivity differential associated with a fibre connection across 2012 and 2014 (i.e. 29.0%);
- α is the estimated elasticity of output to effective labour (i.e. 0.56); and
- ΔU is the gain in employees with access to UFB (i.e. 10 percentage points).

We obtain a result of 1.62% – which represents our estimated increase in real GDP.

17 Conway, P., Meehan, L., & Parham, D. (2015). Who benefits from productivity growth? – The labour income share in New Zealand, *New Zealand Productivity Commission Working Paper 2015/1*. Wellington: Productivity Commission, p.16