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NEW ZEALAND COMMERCE COMMISSION

MODELLING THE IMPACT OF UNBUNDLING THE LOCAL LOOP AND FIXED PUBLIC DATA NETWORK

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1. Introduction

The Telecommunications Act 2001 (the Act) regulates the supply of telecommunications services in New Zealand. It establishes the potential for the local telecommunications network to be unbundled in order to introduce competition in the provision of local services. Under Section 64 of the Act, the Commerce Commission (the Commission) is required to undertake a review of whether access to the unbundled elements of the local-loop network of incumbent, Telecom New Zealand (TCNZ), and access to the unbundled elements of, and interconnection with, TCNZ's fixed Public Data Network (PDN) should be regulated.

Two regulatory scenarios are under review:

- *specification*, which allows non-price aspects to be regulated, with wholesale prices assumed to be set competitively through commercial negotiation;
- *designation*, which allows the Commission to regulate wholesale price if the parties are unable to reach commercial agreement themselves.

OXERA was asked by the Commission to carry out economic cost–benefit modelling in support of this review.[1] This paper outlines the structure of the model constructed to address whether local-loop unbundling (LLU) or unbundling of the fixed PDN should be regulated, and presents the results of the analysis. The analysis focuses on the impact of a regulatory decision on the consumer, compared with a 'counterfactual' scenario—ie, what would have happened in the absence of regulation. The impact of regulation is therefore presented as an incremental change relative to the counterfactual.

Consumers might expect to benefit from regulatory intervention through lower prices and potentially more and better services. This impact on consumers is measured by reference to the consumer surplus that is generated. From an economic standpoint, this surplus is generated by lower prices for the existing installed base (the 'price effect'), plus an increase in take-up (a 'take-up effect') and a potential improvement in the level of service innovation. The methodology by which these effects can be identified is detailed in section 2.6 of this paper.

LLU allows new entrants direct access to the consumer by permitting them to rent the copper loop or physical connection. Voice and data services that compete with the incumbent may then be provided. Hence, LLU can be used to proxy for full facilities-based competition, without the potential efficiency drawbacks of duplicating the local network.

Unbundling can be preferable to service-based competition (using wholesale input services provided by TCNZ), as it allows entrants to provide new and more innovative services over the local network. Wholesale access restricts the entrant to delivering

[1] OXERA was provided with technical advice throughout the project by InterConnect Communications Ltd.

services based on the capabilities of the TCNZ underlying network, likely to be similar to TCNZ's retail offerings.

In general, the competitive provision of data services is a strong *ex ante* rationale for unbundling. The only competition in access that TCNZ currently faces is in certain geographic areas where there is a cable network, as well as some satellite and wireless services. However, unbundling may not necessarily result in a net benefit—there are significant costs involved, including that of establishing the physical point of interconnection, and commercial, technical and operational procedures.

The regulatory options analysed in the modelling are:[2]

- Option 1: Full unbundling;
- Option 2: Line sharing;
- Option 3: Bitstream access;
- Option 4: Unbundling of, and interconnection to, the fixed PDN.

Full unbundling would allow for an entrant to provide both data and voice services over the local loop. *Line sharing*, also known as 'shared access', refers to an entrant providing data services over the high-frequency portion of the copper loop, while TCNZ continues to supply voice services. In both instances of unbundling, the entrant invests in upgrading the local loop and installing the appropriate capital equipment on the exchange side, such as digital subscriber line access multiplexers (DSLAMs).[3]

Bitstream access refers to the situation where the incumbent installs a high-speed access link to the customer premises. This may be through the installation of appropriate ADSL equipment and configuration in the local access network. This access link is made available to other operators, which are then able to provide high-speed services to end-consumers. In effect, bitstream access is the provision of transmission capacity.[4]

The fixed PDN is used to provide a number of distinct data services. Unbundling of, and interconnection to, the fixed PDN would allow entrants access to end-consumers (businesses) in order to provide a variety of data services.

This paper details, in section 2, the economic basis for the methodology adopted in the modelling, and presents the results in section 3. The methodology used is explained in section 4. Data relating to the construction of the model, including prices and costs, is set out in section 5.

[2] Using the scenarios as defined elsewhere by the Commission, Options 1 and 2 together are equivalent to Scenario A; Option 3 corresponds to Scenario B; and Option 4 corresponds to Scenario C.
[3] These would be installed in an exchange (or equivalent) to allow for the provision of DSL services to the end-consumer over the copper loop. The consumer requires an appropriate DSL modem.
[4] See European Commission (2001), 'High Speed Bitstream Access', ONPCOM0-18 Rev 1, September.

This report is a final version of the OXERA draft report published in September 2003 in conjunction with the Commission's draft report. The Commission subsequently received submissions from interested parties, and held a Conference in November 2003, where the issues raised by unbundling were discussed in detail. This report (and the associated modelling) has taken into account the submissions and presentations received by the Commission.

2. Approach to Cost–Benefit Analysis

2.1 Introduction

Any regulatory decision should take into account the ultimate impact on consumers, and such intervention in the market should be motivated by an expectation that it will improve consumer welfare. In this regard, the relative impact on different *firms* within the market (incumbent or entrants) is of secondary importance, subject only to the requirement that any intervention does not impede their ability to deliver the requisite services to consumers.[5]

Any regulatory intervention will affect both consumers and producers, and cost–benefit analysis (CBA) can focus on either or both of these groups, depending on the purpose for which the analysis is being undertaken. In economic terms, the primary group of interest for appraising a regulatory intervention is consumers; producers are of concern only to the extent that the impact of the regulatory intervention may affect the product(s) delivered to consumers. For example, if it is considered that the regulatory proposal may impede investment, either at present or in the future, the effect on producers would need to be examined. However, the producer surplus generated would not be counted as a benefit of the intervention, and, likewise, a reduction in producer surplus (provided it does not impede service delivery or welfare-enhancing investment) would not be counted as a cost of the regulatory intervention.

The objective of the cost–benefit modelling is to determine whether there is a net benefit to end-users—both business and residential—from the various forms of unbundling being proposed. The net benefits are the result of setting the costs of unbundling against the benefits received by consumers, and, if the costs were sufficiently large, the net benefits could be negative, indicating a welfare loss as a result of unbundling.

The driver of consumer benefits is new market entry. For each unbundling option, the model forecasts when it is likely (ie, commercially viable) that firms will enter. Consumers benefit from entry in a number of ways, as a result of competitive pressure:

- price reductions for services they already receive;
- the expansion of existing services to those consumers that cannot currently receive them;
- the introduction of innovative new services.

The CBA is neutral as to whether the net benefits are derived from TCNZ or particular entrants, or even whether entry has to occur for the benefits to be realised. For example, there may be a reduction in TCNZ's prices as a result of the threat of entry, even though

[5] For example, regulators may take into account the impact of price controls on the incentive for firms (especially the incumbent) to continue to invest in the network and/or innovative service provision.

no new entry actually occurs; this effect is not included in the model, but such benefits would be weighted equally with the benefits arising where entry does occur.

Three forms of potential cost result from unbundling:

- the direct costs of undertaking unbundling, such as operation and support system (OSS) costs, incurred by both the incumbent and the entrant;
- productive-efficiency losses, as a result of the reduction in scale economies generated by TCNZ when local lines are unbundled;
- dynamic-efficiency losses, if unbundling (or the threat of it) deters welfare-enhancing investment.

Given the emphasis placed upon efficiency in the Telecommunications Act, an important aspect of the modelling is the extent to which this approach captures efficiency gains or losses (allocative, productive or dynamic) that may result from regulatory intervention. Productive efficiency occurs when goods are produced at minimum cost; allocative efficiency ensures that prices are cost-reflective; and dynamic efficiency results from enhanced levels of innovation and investment in the future.

A CBA approach focused on consumer benefit does not explicitly model efficiency gains or losses. Accurately estimating efficiency gains would be a complex exercise, requiring detailed cost modelling of the incumbent and potential entrants, for which all the necessary information is unlikely to be available. In addition, the cost structure of the industry (high fixed costs and low marginal costs) means that a wide range of pricing behaviour could be considered to deliver a similar degree of allocative efficiency. Furthermore, estimation of dynamic efficiency may be speculative since it is entirely forward-looking.

An alternative to modelling the efficiency impacts directly is to estimate the consumer benefits arising from liberalisation. This approach has the advantage of implicitly capturing the allocative- and productive-efficiency gains arising from increased competition, which are passed on to consumers, while disregarding those that are reinvested by the firms or retained as profit.

Two issues that are not directly captured by the methodology, however, need to be addressed: the extent of the negative impacts of unbundling on the incumbent's productive efficiency, and any potential effects on future investment that may lower dynamic efficiency.

In its submissions in response to the draft report, and at the Commission's Conference, November 10th–14th, TCNZ argued that unbundling would result in a loss of economies of scale of operation. Its arguments about the negative impacts of unbundling are derived from the Charles River Associates report, reproduced as Annex A in TCNZ's submission on the draft report. In particular, this raises a number of reasons why the anticipated negative results are likely to arise (see para 154), which can be paraphrased as follows. Unbundling could:

- reduce investment incentives to improve productive efficiency, as entrants would also gain;
- lead to a loss of economies of scale and/or additional costs;
- result in substantial regulatory costs.

Each of these issues is now considered in turn.

While it is conceivable that unbundling could reduce incentives for further investment to drive productivity growth, this is not supported by international evidence. OECD (2001) documents a number of countries where significant investments in the local access infrastructure have continued to be made following unbundling.[6] These include the USA, Germany, Canada, France and Ireland.

This suggests that it is unlikely that TCNZ would reduce its productive-efficiency-enhancing investment as a result of unbundling. Furthermore, withholding this investment implies that TCNZ itself would also not benefit from any available cost savings. The results from the CBA modelling suggest that, at most, around 80,000 lines would be unbundled (in Option 3), compared with a total number of access lines in New Zealand of around 1.7m. Given that this implies unbundling of a maximum of 5% of access lines, the cost savings to TCNZ on the remaining unbundled lines are likely to significantly outweigh any adverse effect from allowing unbundling entrants also to gain from this investment. On this basis, it would not seem plausible for TCNZ to withhold such investment.

Similarly, there may be a loss of economies of scale from unbundling, although it is difficult to accept this proposition without substantive empirical evidence. Ideally, this would be in the form of a detailed cost study of TCNZ's network, identifying exactly what equipment would need to be deployed, how this would affect TCNZ's network operation, and estimates of the change in unit costs as a result of the loss of the unbundled local loops.

TCNZ did not undertake such a cost-estimation exercise. Furthermore, Charles River Associates presented few, if any, empirical studies to support its own conclusions on the negative impacts of unbundling. Indeed, a detailed literature search reveals that there are few empirical analyses of the impact of unbundling on the productive efficiency of incumbent telecommunications firms. The research that does exist indicates that the potential losses of economies of scale from local-loop competition are small, and likely to be outweighed by the gains from competition.[7]

Thus, neither a detailed cost analysis nor relevant empirical research supporting TCNZ's proposition has been presented, which makes it difficult to substantiate a change to the assumption in the draft report that the effects on economies of scale for the incumbent would be minimal.

[6] OECD (2001), 'The Development of Broadband and Information Services Policies', Working Party on Telecommunications and Information Services Policies.
[7] See Correa, L. (2003), 'Natural or Unnatural Monopolies in UK Telecommunications', Department of Economics, Queen Mary, University of London, Working Paper No. 501, September.

The final issue raised by TCNZ was the matter of the burden of regulatory costs. However, this is largely endogenous to TCNZ's own behaviour, and is therefore a cost under its own control, rather than a function of unbundling per se. For modelling purposes, the Commission provided estimates of reasonable regulatory costs that are likely to be incurred by TCNZ and potential entrants.

In addition, many studies indicate that the introduction of competition in telecommunications markets previously dominated by an incumbent monopoly can yield substantial consumer benefits.[8] These benefits take the form of improved productive and allocative efficiency, as well greater innovation and improved service levels (considered below).

On balance, unbundling would appear to be more likely to result in net efficiency gains than losses, although, as discussed, some negative effects might arise. For this reason, the modelling uses conservative estimates for the productive-efficiency catch-up estimate and the allocative-efficiency (profitability) gain. These are more likely to underestimate than overestimate the true welfare impacts of unbundling.

In its main report, the Commission concluded, on the evidence available to it, that it could not be satisfied that unbundling would create sufficient negative investment incentives such that would the dynamic efficiency gains achieved though competition would be outweighed.

In summary, therefore, rather than dynamic-efficiency losses from unbundling, it would seem likely that there would be gains. In terms of the cost–benefit model, given the uncertain nature of dynamic-efficiency gains, it is not possible to estimate them explicitly. Rather, it can be posited that there are likely to be greater dynamic-efficiency gains as a result of introducing competition than those included in the modelling.

2.2 Unbundled products

This section considers the services that have been modelled for the purposes of the CBA. Two types of service can be delivered to consumers through fixed copper telephone wires: voice and data. While voice services are reasonably static in their characteristics and current innovation relates mainly to tariff structure or related value-added services (eg, call minding),[9] data services are potentially very varied.

[8] See, for example, Li, W. and Xu, L. (2002), 'The Impact of Privatisation and Competition in the Telecommunications Sector around the World', Darden Graduate School of Business Administration, University of Virginia. Ros, A. (1999), 'Does Ownership or Competition Matter? The Effects of Telecommunications Reform on Network Expansion and Efficiency', *Journal of Regulatory Economics*, **15**:1. OECD (2002), 'Closing Statement: OECD Conference on Telecommunications Policy for the Digital Economy', Dubai, January 22nd. Boyland, O. and Nicoletti, G. (2001), 'Regulations, Market Structure and Performance in Telecommunications', OECD Economic Studies, 32, 99–142.

[9] It is for this reason that voice services are often referred to as POTS—plain old telephony services. However, at the Conference, there was extensive discussion of the conversation to voice over Internet Protocol (VoIP). This is a

The standard services provided using data capacity (the high-frequency bandwidth on the copper access pair) are data transmission, including access to the Internet and email. However, many more uses can be made of the data capability, including information services, VoIP, and, ultimately, video over the fixed wireline. VoIP and video over the fixed wireline are currently at the edge of commercial feasibility, and have been rolled out only on a small basis in a few countries, although many trials are being undertaken.[10]

Given the scope for increasing the diversity of data services available to consumers and the standard nature of voice telephony (with the exception of VoIP), the most attractive commercial proposition for new entrants usually relates to data services. These offer the greatest opportunity to deliver value-added products to consumers, and hence to extract higher revenues. For this reason, entrants in most countries around the world have unbundled the local loop primarily in order to provide data services.

For tractability, it is necessary to use only a single product in the modelling (ie, a single representative product for each of the business and residential segments). However, there are many different products currently available on the market, and it is likely that even more will be provided in future as a result of investment and innovation.

To generate a price for a representative product, a weighted average of the September 2003 prices is calculated for the different TCNZ products that are available. This effectively produces a standardised product consumed in 2003, and the model predicts the effects of changes in its price. In practice, for LLU and bitstream, this is a weighted composite of the various Jetstream products currently available.

There was extensive discussion at the Conference about the likely new services that will be delivered in the foreseeable future. In particular, the bundle of products available to consumers is likely to expand, although the average amount they spend each month may remain reasonably constant. This service innovation could be one of the significant benefits of LLU, as entrants cannot deliver new services through the existing wholesale access provisions.

However, the innovations proposed by both TCNZ and prospective new entrants have both uncertain characteristics and an unknown consumer valuation. As a result of this uncertainty, it is not possible to model explicitly these potential innovations.

Thus, the modelled services that are expected to be unbundled are data and (for full unbundling only) voice. While the latter has not generally been an attractive service for entrants to provide elsewhere in the world, the situation in New Zealand is potentially

technological innovation, but the service presented to the consumer would not fundamentally change in its characteristics.

[10] Although cable networks currently provide television over a fixed wireline, they do this by separating services between two cables. Television and data services are provided on one cable, while a separate dedicated cable carries the voice service. In contrast, provision of data services (potentially including television) over PSTN lines involves a single wire for both data and voice, complicating the spectrum management issues.

different, as TCNZ only relatively recently became subject to sector-specific regulation. As a result, TCNZ might continue to earn substantial returns on its voice services.

In principle, this outcome would suggest that voice services could also provide entrants with considerable opportunity to earn a reasonable profit. However, the standardised nature of voice services means that it is straightforward for TCNZ to respond aggressively to any new entrant with regard to price. Furthermore, the lack of geographical averaging means that the response to entry may be selective. Given that TCNZ, as the incumbent, has already sunk its investment costs and hence faces a lower cost (even if all other costs were equal) than a new entrant, the risks for an entrant unbundling voice-only services would be high.

Therefore, notwithstanding the absence until recently of any sector-specific regulation of TCNZ's voice services, it is assumed that an entrant's principal reason for unbundling is to provide data services, and they would not unbundle an exchange solely to provide voice services. However, as noted, the unbundling options under discussion allow the entrant to unbundle the whole copper loop to provide both data *and* voice services to consumers (full unbundling); or to unbundle only to deliver data services, with TCNZ continuing to provide voice telephony (line sharing). Line sharing is technically more complex in terms of spectrum management, and hence is more costly at the wholesale level.

Where an entrant has unbundled an exchange to provide voice and data services, it is assumed that they will also provide voice-only services to any consumer wishing to take them. This is because, while the risks of unbundling solely for voice may be significant, the incremental costs of providing voice-only services once the exchange has already been fully unbundled (for data and voice combined) are negligible.

Having identified the product(s) to be unbundled, a number of questions must be addressed in the modelling:

- where does new entry occur?
- what happens in the absence of new entry?
- how are retail prices likely to change following entry?
- how should the benefits to consumers be valued?

Each of these questions is considered below, along with an outline of the approach that has been adopted.

Where assumptions have to be made, the overall approach of the model is to be conservative. That is, where choices have to be taken regarding the model's components, the option that would reduce the likelihood of entry occurring has been selected. For example, if there is a range of reasonable values for a particular cost entering into the designated price or costs of entry, the higher end of the range has been selected. The rationale behind this approach is that the model is more likely to under- than over-predict the level of entry, and it thus errs on the side of caution. This reflects the balance of risks in a regulatory decision: there are usually greater risks attached with intervening in a market in an incorrect manner than deciding not to act. The latter provides the option to intervene at a later date.

2.3 Where does new entry occur?

TCNZ is in the process of upgrading many of its local exchanges to digital data capability through the installation of DSLAMs, inter alia. This allows the bit rate to be increased to provide high-speed data transmission. In the first instance, this is asymmetric (ADSL), with considerably greater speeds downstream than upstream.[11]

One of the characteristics of ADSL is that the further the customer is located from the local exchange, the more the bit rate degrades. Therefore, to ensure that a reasonable number of customers can be provided with the same service, the highest bit rates are often not guaranteed, especially to rural customers. In general, only those customers sufficiently close to the exchanges may receive higher line speeds, and this usually produces a distance cut-off point of about 7km for ADSL services.

It is possible to upgrade lines to provide a guaranteed symmetric line speed of 2 Mbps or higher through the use of other technology, such as SHDSL (symmetric high-speed digital subscriber line), although customers must usually be within 2km of their local exchange to take advantage of these higher speeds. The advantage of such high committed rates is that more advanced and bandwidth-intensive services, such as linear broadcast television,[12] can be provided over telephone lines.

For the CBA, it is assumed that TCNZ and the entrant(s) will upgrade to provide ADSL services only, although at least one of the potential entrants that replied to the Commission's Issues Paper considered that it would aim to provide SHDSL services, as TCNZ does through its NGN.

When deciding whether to enter at a particular exchange, an entrant will take into account the following aspects:

- whether the lines are technically upgradeable;
- the likely take-up of broadband services; and
- commercial viability.

2.3.1 Technical capacity

Not all lines in a local exchange can be provided with high-speed data services. The lines available to an operator upgrading the exchange are therefore likely to be a subset of the total number of lines in that exchange-serving area (ESA). Hence, the first calculation for an entrant (or TCNZ) is the number of lines that could be technically upgraded. This calculation involves establishing the number of lines within the required distance from the

[11] The downstream rate (ie, towards the customer) is up to 2 megabits per second (Mbps).

[12] This is distinct from video-on-demand (VoD) services. With appropriate receiver equipment (ie, a hard disk drive), VoD services can be provided as a download rather than streamed content. This requires a considerably lower bit rate than streamed video, of which linear broadcast television would be an example. Hence, downloadable VoD services are feasible over standard ADSL connections, while broadcast television is not.

exchange. Also, as discussed above, this is a function of the committed line speed that the operator wants to offer; in the model, the cut-off for ADSL is taken to be 7km (although this assumption can be varied).

Other technical characteristics of local lines that can make the upgrading of relevant lines impossible, or at least considerably more expensive, include the existence of sub-loops, where lines are served from a cabinet that is remote from the exchange itself, and may be connected to the exchange by optical fibre or some other form of distribution line. For spectrum management reasons, it is not possible to serve sub-loops from a DSLAM sited in an exchange, especially if TCNZ has already upgraded the lines by placing a DSLAM in the cabinet itself. As cabinets are very small, there may be insufficient space to accommodate an entrant's DSLAM as well as that of TCNZ (even when using mini-DSLAMs). Moreover, it may be uneconomic for two firms to serve the small number of end-user lines connected to a sub-loop.

As a result, the number of technically upgradeable lines in the model excludes any lines sited on sub-loops. Although this may not reflect actual practice in all cases, in terms of the CBA it is a conservative assumption because it reduces the number of subscribers that might receive upgraded services and the benefits of competition.

Further technical issues to be taken into account concern those lines connected with non-copper distribution lines, such as those employing pulse code modulation (PCM). As PCM inhibits the deployment of ADSL services, these lines have been excluded. There may also be spectrum management issues relating to interference between lines within a cable sheath. Evidence from Australia suggests that, in practice, the likelihood of this causing a material deterioration in service is very low (around 1%); the central case in the model therefore assumes that the reduction in serviceable lines due to interference is zero, although this interference factor could be modified.

These adjustments yield the number of technically upgradeable lines in each ESA, which form the baseline volume for the subsequent analysis.

2.3.2 Take-up of broadband services

Having established the number of technically feasible lines for upgrading, it is necessary to identify the likely purchase of broadband by consumers. Not all consumers are interested in high-speed data services, and, of those who are, not all can afford them. As the decision of whether to upgrade an exchange is a commercial one, the potential demand for the services must be established.

At present, New Zealand has a high level of total Internet penetration by household, relative to other countries, and this is mainly narrowband dial-up rather than broadband. Indeed, there are only around **[✂] TDR** residential ADSL subscribers in the country. The level of Internet access also varies between the different geographic areas in New Zealand.

To identify the profile of take-up of broadband services across the modelling period, two alternative approaches can be adopted: a modelling approach based on reasonable assumptions, or a third-party estimation of future demand. In the draft report and model, OXERA adopted the former approach, deducing reasonable assumptions and using these to generate the counterfactual and scenario outcomes. For the final model, the Commission requested that the take-up profile and penetration rates be adjusted so that the counterfactual in the model replicated TCNZ's projected broadband subscription rates to 2010.

The model generates the projected number of broadband subscribers by assuming that a proportion of those households currently purchasing Internet services would, over time, adopt high-speed services. Therefore, the penetration rate (of broadband) is likely to be a percentage of the present and future Internet usage rate. To replicate TCNZ's take-up figures for the counterfactual, it is assumed that up to 35% of *Internet* households will take broadband. This is adjusted upwards in the options to account for the increased market-penetration (elasticity) effects of any price reductions that result from competitive entry.

This methodology is illustrated in Table 2.1. The percentage of Internet households is multiplied by the base percentage to produce the penetration rate for the counterfactual. For example, this would be 17.9% (35% × 51%) for metro areas. In the scenarios there is a price fall, which is combined with the elasticity effect and the base percentage to produce a moderated base percentage. As above, this is multiplied by the percentage of Internet households to determine the penetration in the scenarios.

Table 2.1: Calculation of the penetration rate (%)

Area	Internet penetration 2003 (households)	Base percentage	Price fall	Elasticity	Moderated base percentage	Penetration rate
	(A)	(B)	(C)	(D)	(E=B+(C x D))	(E x A)
Metro	51	35	15	–1.5	57.5	29
Urban	36	35	15	–1.5	57.5	21
Suburban	39	35	15	–1.5	57.5	22
Rural	43	35	15	–1.5	57.5	25

Source: OXERA analysis.

An identical process is used for business penetration of broadband, but in this case the initial Internet penetration (equivalent to column A) is 85%, and the base percentage is 40% (column B).

This relationship was used to generate the total likely penetration of broadband services for both business and residential customers for any given price level, which, in the absence of any rationale to make adjustments by geographic region, was applied uniformly to all ESAs.

However, consumers will not switch to broadband immediately; as with any technological product, there will be a gradual adoption as consumers become more aware of the service and its characteristics. An adoption profile has therefore been generated that moderates the speed with which the penetration increases towards its determined maximum. The adoption rate in the draft report was derived from the historical take-up of personal computers (PCs) in New Zealand. For the final report, the glide path for business and residential customers was modelled separately and configured in order to approximate TCNZ's expected customer take-up.

In addition, it is recognised that not all consumers interested in broadband will take ADSL. Some will take high-speed services from other providers using alternative infrastructures, such as cable, satellite or wireless. Similarly, existing subscribers to these alternative technologies may churn back to ADSL wireline services as prices fall. As non-ADSL networks are not explicitly modelled, this effect is accounted for by a percentage net churn of potential ADSL subscribers each year to non-ADSL services. This has the effect of further reducing the potential subscribers available to TCNZ and the entrant(s).

Having combined all these adjustments, the model produces an estimated proportion of the total technically feasible number of lines that are likely to take ADSL services in each ESA every year. This is split between business and residential subscribers, and, in each case, is allocated between TCNZ and the entrant(s) in each year. The apportionment mechanism takes into account two assumptions:

- when LLU is introduced, there is a net churn to the entrant(s) from TCNZ's installed base of subscribers in those exchanges that it has upgraded;
- new subscribers (ie, those that do not take DSL at the beginning of the year, but are projected to take it up during the year) are apportioned between TCNZ and the entrant(s) on the basis of a competitive market-share rate.

2.3.3 Commercial viability

An entrant's decision to enter the market is determined on the basis of whether it is a commercial proposition—ie, whether it is likely to be profitable. Therefore, in modelling the impact of LLU, it is necessary to replicate this decision process. The model does this through a net present value (NPV) calculation of the costs and benefits to the entrant, for each ESA. If the NPV of entry is positive, it is assumed that entry will occur; if negative, there will be no entry. The discount rate for the NPV calculation is the appropriate cost of capital, thus ensuring that the entrant can make an adequate return.

The inputs to the NPV are the costs/revenues that the entrant will incur/receive. The costs are broken down into sub-categories covering: the one-off costs of setting up the LLU regime; the one-off costs of unbundling a particular line, which arise when a customer is first connected; and the fixed and variable charges of supplying a customer each year.

Revenues are based on the prevailing price level in any particular year, and comprise a fixed connection charge for each new subscriber and a monthly fee for the service.[13]

In theory, there could be a valuable option for the entrant to delay its investment in order to enter the market, as discussed by Dixit and Pindyck.[14] However there are a number of reasons for considering that the actual option value would not, in practice, be significant:

- the option to defer is not a free option, in that other firms could exploit (and, in the case of TCNZ, already are) the opportunity to which the option relates. Other

[13] As the model operates on an annual basis, the monthly fee is aggregated up to the annual level through a simple sum; there are no within-year discount factors.

[14] Dixit, A. and Pindyck, R. (1994), *Investment Under Uncertainty*, Princeton University Press.

firms could enter as unbundled entrants, which could reduce or remove the opportunity for the delaying firm to enter in the future. Moreover, TCNZ is currently developing its broadband proposition and increasing its installed base of customers. All these developments will significantly reduce the expected revenue stream following a delay;

- the option will have a finite and relatively short lifetime, as it would become considerably more difficult for the entrant to compete with TCNZ after even two years, due to TCNZ's first-mover advantage. At present, as broadband services are only just beginning to develop, an opportunity exists for entrants, although this will not remain the case for long; and
- the actual quantum of sunk costs incurred by the entrant will be small relative to the other assets owned by the entrant and employed at the local exchange level over the lifetime of the project—the only costs likely to be deemed to be sunk will be the collocation set-up costs, as other investments (eg, backhaul links) could be used for other purposes;

Overall, therefore, if the actual option value were to be calculated, it is unlikely to be substantial, and any premium on the weighted average cost of capital (WACC) would be insignificant. As a result, this issue is not considered any further in the analysis.

The NPV function in the model multiplies these costs and revenues by the relevant number of subscribers, and calculates the resulting NPV, were entry to occur. This is carried out twice for each scenario to allow for differing levels of entry that reflect different prices. It is assumed that the maximum number of entrants in any ESA will be two, and that, if two firms enter, the competitive price will be achieved.

The first entry cycle calculates the NPV with only one entrant, and therefore assumes that the market price will be above the fully competitive level. If this NPV calculation is positive, at least one entrant would offer services. The second cycle does the same for two entrants at the competitive price level. If the second cycle is positive, two-firm entry is predicted.

Therefore, the result of the NPV calculation is that the model predicts the ESAs in which one firm, two firms or no firms will enter.

2.4 Retail price effects following entry

The relevant retail price is the price that consumers must pay to use broadband services. Given that broadband is of little use to residential customers without an Internet service provider (ISP) for Internet access and e-mail, the price should include ISP costs. Furthermore, most, if not all, businesses also access the Internet, and so would also need an ISP. The broadband connection may be used for other forms of data transfer, but these firms would still incur an ISP charge, which comprises a monthly access charge payable to the local telecommunications access provider (currently only TCNZ), plus a monthly charge payable to the ISP. The only exception to this is the fixed PDN service that is modelled as a composite of Frame Relay and Digital Data Services (DDS) distributing data between branches of a particular firm.

The counterfactual prices generated for the representative products form the 2005 prices in the model. In the options the prices gradually fall over five years to reach the required level, either P_1 or P_2—ie, there is a price glide path that determines the actual price faced by consumers in any particular year. Thus, the full price reductions predicted by the model are applied over time.

The primary benefit to consumers from LLU is likely to be an increase in competition in the provision of services over the local loop. This should reduce the price of existing services and increase the diversity of new services offered. As discussed, the latter is a feature of dynamic efficiency, and the consequent benefits have not been quantified in the modelling.

The effects of the price changes in the model are twofold: they produce a benefit for those consumers that already take broadband, and they result in higher take-up of services by consumers through the penetration rate. This latter effect is produced by the application of a price-elasticity factor combined with the price reduction.

Price benefits result from greater competitive pressure on TCNZ and on all firms providing retail services to consumers. If the current (pre-LLU) price is not at the most efficient level, because of either allocative inefficiency (excess profitability) or productive inefficiency (producing at a cost greater than that indicated by the efficiency frontier), competition should help to reduce price. This will result from either an erosion of margin—and hence increased allocative efficiency—or a reduction in excess production costs.

As noted, the assumption is that the optimum competitive price level is only obtained when there are two entrants, resulting in three competing companies in the market. It is also assumed that the price fall will not materialise in the first year, but will be spread over five years. This produces a glide path for prices as they gradually fall, reaching the final competitive price (100% of the price reduction) in year 5.

If there is only one entrant, it is unlikely that the market will be fully competitive; the price is therefore assumed to be between the current price and the fully competitive level. Again, the price falls over time, reaching its final level after five years. Section 5 details the prices used and how they were derived.

The price impacts have been modelled on a de-averaged basis, with the minimum level of price formation being the ESA. Although TCNZ could, in principle, set different prices by individual customer, even for residential consumers, it generally uses a higher level of aggregation as a basis for setting prices. The assumption in the model is that this level is the ESA, which appears to be broadly consistent with TCNZ's current practice.

It is also assumed that the effects of competition are restricted to the ESA within which competition arises, rather than there being spillover effects into contiguous ESAs, or even across the whole country. If competition stimulated by unbundling were deemed to have a general effect, leading to a fall in prices in all ESAs, there would be considerably greater welfare effects. To this extent, the model is conservative and will estimate a lower level of benefit from unbundling than would be the case if stronger assumptions were used.

2.5 Market outcome in the absence of entry

At present, TCNZ has no obligation to set an average, or standard, price across New Zealand; it is able to price in response to entry in a very localised manner. The model therefore assumes that any price benefits arising from the introduction of LLU are limited to those exchanges where entry occurs; all others remain with the TCNZ price forecast for the period. This is a conservative assumption because there may be an effect of general competitive pressure in the market that forces TCNZ to lower its prices across all, or a substantial number of, its exchanges. If this were the case, many more subscribers would be affected, and the benefits resulting from LLU would be correspondingly greater.

Even without entry, it is assumed that there will be a general reduction in retail prices over time, as a result of technological developments leading to cost reductions, and that the impact of the Commission's wholesale decision will place some competitive pressure on prices. In other words, in the counterfactual (as well as Options 1, 2 and 3), prices fall by 5% over the five-year modelled period. In Option 4 (unbundling of the fixed PDN), prices fall by 3% over the period. This is a variation from the draft model where the counterfactual (and implicitly the prices in the options) were assumed to be static in real terms.

Telecommunications technological innovation, in particular, may be reducing the underlying input prices for firms at a faster rate than 5% (or 3%) over five years. However, the important aspect for consumers is the extent to which these benefits are passed on in the form of lower prices. As noted, even with the effects of the wholesale determination, it is likely that, absent unbundling, TCNZ will face only limited price pressure across most of New Zealand in the foreseeable future. Accordingly, a 5% (or 3%) reduction in prices would appear reasonable.

2.6 Valuing consumer benefits

Having identified all the relevant components of the likely market development over the relevant period, the consumer benefits arising from LLU can be calculated. As noted, these benefits take two main forms:

- **price effects** that arise for existing subscribers as a result of the regulatory options. These are straightforward to calculate as they represent the difference between the option and counterfactual prices; and
- expansion of the market through lower prices and increased availability of services in areas where the exchange was not previously upgraded. All subscribers benefiting from the increased availability of services do not gain a price benefit (as they did not previously pay the higher price), but they do gain an increase in their consumer surplus by receiving services they did not previously have. This **take-up effect** is the difference between their willingness to pay and the amount they actually paid for their broadband services.

Figure 2.1 illustrates these two benefits in a relatively simple framework. P_0 is the price in the counterfactual (ie, with no regulatory intervention); P* is a representative (lower) price, following regulation.[15] Q_0 is the number of subscribers in the counterfactual (ie, with no regulatory intervention); Q* represents the (increased) number of subscribers following intervention.

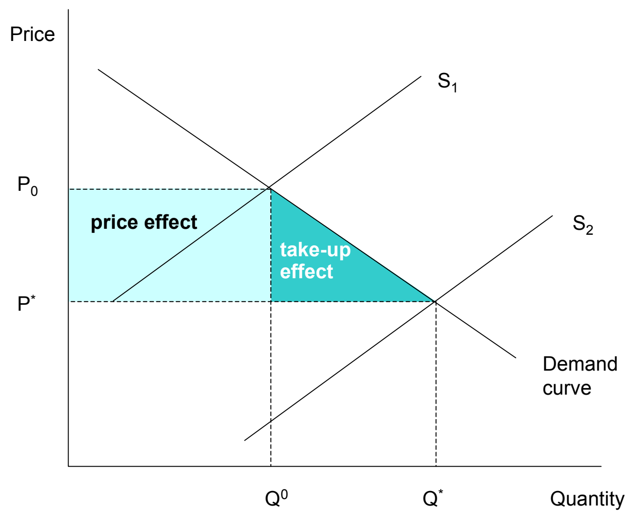
The price effects enjoyed by the existing installed base are represented by the rectangle. Mathematically, this area is equal to:

$$(P_0 - P^*) * Q_0$$

The take-up effect is represented by the triangle. Mathematically, this area is equal to:[16]

$$(P_0 - P^*) * (Q^* - Q_0) * 0.5$$

Figure 2.1: Representation of the benefits to consumers



Note: This figure is purely illustrative. It is not drawn to scale, and should not be taken to represent the actual results.

The effects of unbundling have been modelled in a comparative static framework—ie, many of the key market characteristics have been maintained as stable, particularly the product set being offered. Other than market entry (with its consequent efficiency effects on price), the only other parameter that varies in the final version of the model is the underlying cost structure. This is assumed to drop such that prices fall by 5% in both the counterfactual and the options.[17] This feature was not incorporated in the draft version of

[15] This figure is purely illustrative. It is not drawn to scale, and should not be taken to represent the actual results.
[16] This calculation is an approximation, since the actual size of the triangle would depend on the shape of the demand curve, which has not been explicitly estimated.
[17] In Option 4 (unbundling the fixed PDN), this figure is 3%.

the model, but the Commission requested that this change be implemented for the final version of the model. The impact of this change is to shift the supply curve outwards in both the counterfactual and options (for simplicity this is not shown on the figure above).

The analysis uses a standard or Marshallian demand curve (also known as an 'uncompensated' demand curve).[18] It shows the relationship between the price of a good and the quantity purchased, taking into account the fact that the utility derived by an individual from a purchase increases as the price falls. The Marshallian demand curve reflects what is likely to occur in reality.

A compensated demand curve, on the other hand, is constructed to keep the individual's *real* income (or utility) constant as the price of the good changes. For example, as the price of the good falls, the individual's nominal income is effectively reduced to prevent any increase in utility. The opposite would be true of an increase in the price of the good. In both instances, the effects of the price change on purchasing power are 'compensated' to keep the level of real income or utility constant. In general, a compensated demand curve is less responsive (ie, less elastic) to price changes than an uncompensated demand curve.

The choice of which type of curve to use depends on the objective of the work and information available. For empirical work, uncompensated demand curves are often used, as the price and demand data needed is most readily available. For some theoretical work, compensated demand curves may be the most appropriate choice, particularly when measuring the welfare effects of a price change. However, the location of the compensated demand curve depends on the target level of utility assumed—should it be the level of utility before or after the price change? This choice will affect the size of the welfare change (ie, the consumer surplus measure).

Fortunately, the Marshallian (uncompensated) demand curve is a good compromise between the two compensated curves, as it falls between them. Moreover, information in the Marshallian curve is more likely to be available from actual market data. Furthermore, where the price changes are small, the difference between the three curves would also be small.

As noted in section 2.1, a further form of benefit arises from the increased bundle of services (the dynamic benefits). Such changes to the products supplied would produce an entirely new demand curve that reflects the underlying demand for the components of the new product bundle. It is likely that this new demand curve would have a different position to the demand curve for the simple data product shown in Figure 2.1, and would probably have a different slope.

[18] The following discussion draws heavily from Nicholson, W. (1994), *Microeconomic Theory—Basic Principles and extensions,* The Dryden Press.

The benefit from unbundling would depend on the extent to which the new services would not otherwise have been supplied (ie, without unbundling). For example, if the services are delivered solely as a result of innovation from unbundling entrants, the full consumer surplus benefit could be accorded to the relevant unbundling option. More likely, however, is that the new services would have been provided to consumers, but unbundling speeds their introduction and lowers their price(s).

While it is possible to outline the theoretical approach to determining the dynamic benefits of unbundling, the practical estimation is complex without consumer surveys and econometric estimations of consumers' valuation of the different services that become available. As none of these was readily available, the dynamic benefits have not been estimated.

3. Results

As noted in section 1, the focus of this CBA is the potential gains to consumers from regulatory action—either specification or designation. Therefore, the only gains that are relevant are those that are incremental, as a result of regulatory intervention. As described in section 2, the benefit (or loss) that is due to regulatory action is calculated by comparing welfare gains with the outcomes in the counterfactual.

Potential gains to consumers are reflected in a choice of services from more operators at lower prices. As discussed in section 2, in economic terms, these are proxied by measuring the welfare gains to consumers that result from two effects:

- the **price effect**, where existing consumers benefit from a reduction in the retail price;
- the **take-up effect**, where the price falls lead to an expansion in take-up.

Together, these constitute consumer surplus.

Table 3.1 reports the consumer surplus gains over the base case that result in each scenario using the central case assumptions detailed in section 5, many of which can be varied. A sensitivity analysis for certain variables is set out in section 3.1.

Table 3.1: Present value of consumer surplus, 2005–09 (NZ$m)—base case

Option	Specification			Designation		
	Price effect	Take-up effect	Total	Price effect	Take-up effect	Total
1: Full LLU	0.4	0.5	0.9	49.1	34.7	83.8
2: Line sharing	5.3	0.3	5.6	81.0	32.3	113.3
3: Bitstream	12.8	1.0	13.9	121.8	49.0	170.8
4: Fixed PDN[1]	55.1	–	55.1	232.4	–	232.4

Note: [1] The take-up effect for the fixed PDN is zero because it is assumed that new demand cannot be stimulated by the entrant, and that all existing data tails are being used when unbundling occurs. Therefore, the entrant only gains by churning customers from TCNZ, and no new subscribers join as a result of unbundling.

The results show that there is a positive gain to consumers from regulation in all options and scenarios, although, in designation, where the gains are greatest due to larger price falls (see Tables 3.2 and 3.3), these are more heavily skewed towards business than residential customers.

The ordering of benefits from the unbundling scenarios is consistent between the four options (designation always generates greater benefits than specification).

The higher benefits from bitstream access (Option 3) compared with Option 2 reflect the fact that there is a lower total cost of providing the unbundled service, because collocation costs are avoided. In addition, entrants face a lower risk of investing in network components (eg, DSLAMs) that might not be fully utilised. This option is consequently more attractive, entry occurs at more exchanges and hence the market expands more.

Overall, the model predicts the highest benefits for unbundling under bitstream where prices move closer to costs as a result of regulation (excluding the specialised services offered by the fixed PDN). The other forms of access also show significant benefits. There are substantial gains to existing customers of the fixed PDN following the liberalisation of this service.

Tables 3.2 and 3.3 report the price falls that underpin each scenario, split between business and residential. Table 3.2 reports the decline from P_0 to P_1, and Table 3.3 from P_0 to P_2. (These price declines are from a starting year P_0 to a year 5 P_2, both of which exclude the additional price drop due to cost pressure and the wholesale decision).

Table 3.2: Retail price falls (P_0 to P_1) over the CBA, as a result of unbundling (%)

Option	Specification		Designation	
	Residential	Business	Residential	Business
1: Full	–17	–4	–25	–48
2: Line sharing	–22	–1	–25	–53
3: Bitstream	–22	–1	–27	–54
4: Fixed PDN		–7		–30

Table 3.3: Retail price falls (P_0 to P_2) over the CBA, as a result of unbundling (%)

Option	Specification		Designation	
	Residential	Business	Residential	Business
1: Full	–24	–12	–31	–52
2: Line sharing	–28	–9	–31	–56
3: Bitstream	–28	–9	–32	–56
4: Fixed PDN		–16		–36

The welfare gains shown in Table 3.1 are derived from the price reductions over the counterfactual that result in lower prices to existing customers and an increase in the DSL subscriber base. The price changes come about as a result of competitive pressure from unbundling. The results are therefore sensitive to both the assumptions underlying the relevant costs and revenues and those used to predict take-up. Overall, the assumed retail price falls, even under designation, do not look out of line with observed outcomes in other jurisdictions.

Any regulatory intervention would be concerned with the level of wholesale access charges, but the difference in benefits between the specification and designation scenarios (resulting from the different price reductions) is driven by the assumptions on the way in which the *retail* prices are derived, and the ensuing entry decisions. In specification, they are set using a top-down approach, while, in designation, they are determined using a cost-based approach. The latter approach may result in lower retail prices, driving the higher welfare benefits.

Wholesale access prices are implicitly included in the specified prices, and explicitly included in the bottom-up approach to the designated prices. The difference in wholesale prices between specification and designation depends on the relative strength of the bargaining position of entrants under specification. It may be argued that marked differences could not persist between the negotiated outcome for wholesale prices under specification and cost-based wholesale access prices under designation—any initial differences would be eroded by entrants threatening to ask the Commission to designate the service. However, a conservative approach has been adopted here that yields differences between prices in specification and designation, and could thus understate benefits in specification.

The number of additional subscribers taking data services in Options 1 to 3 is shown in Table 3.4. For both residential and business customers, the greatest number of customers is gained in Option 3 (bitstream), in specification as well as designation.

Table 3.4: Number of customers gained at 2009 as a result of unbundling

Option	Specification		Designation	
	Residential	Business	Residential	Business
1: Full	2,771	2,467	7,360	29,585
2: Line sharing	5,573	2,585	8,576	44,295
3: Bitstream	14,965	5,916	18,397	64,798

Source: OXERA calculations.

As the costs and benefits modelled are either financial, or have been converted to a financial measure, there are certain aspects of LLU that have not been taken into account. For example, experience around the world suggests that collocation is difficult to organise, even with regulatory intervention. Such problems are likely to increase the difficulty of entry and thereby limit the number of successful entrants. These costs have not been modelled, but would suggest that entry under full unbundling or line sharing may be delayed compared with bitstream services.

To place the results in Table 3.1 into context, a range of prices has been developed by altering two key assumptions in the price-determination process. This generates a low- and a high-price scenario, which produce welfare estimates that provide a range around those in the central case (Table 3.1). These estimates do not present a formal statistical range of welfare benefits, such as a confidence interval; rather, they illustrate the range of welfare benefits that is likely to result from altering a number of parameters central to price formation in the scenarios.

The altered parameters (see Table 3.5 below) were, for specification, the OSS costs and the profitability and efficiency estimates for specification, and, for designation, the OSS costs and the number of lines across which fixed and set-up costs are spread. One case is termed the 'low case' because it produced high prices and thus presents a lower-range estimate of welfare benefits, while the other, 'high case', has low prices and thus sets an upper-range estimate of welfare benefits.

Table 3.5: Parameters for welfare range estimates

	Low case (high prices)	High case (low prices)
Specification		
OSS ($/line)	18.4	0
Profitability	2.5%	7.5%
Efficiency	1.25%	3.75%
Designation		
OSS ($/line)	18.4	0
Number of lines	500	2,000

The results for specification show that the low case (high prices) results in negative welfare benefits from all the options except the fixed PDN. This is a result of P_1 being above P_0 in some cases, especially for residential services and business and residential voice services in Option 1. However, as voice subscribers are not subject to the elasticity effects of price shifts (because it is assumed that this is an essential service), the revenues from the combined data and voice services are sufficient to drive entry in Option 1. In the other options the higher prices generate more revenues for the entrants, albeit from fewer customers than in the central case, which are sufficient for entry.

In the high case (low price), there is a trade-off between a lower price that stimulates additional demand and the lower per-customer revenues gained by the entrant. The results indicate that the market-expansion effect dominates and there is more market entry, which, combined with greater welfare gains per consumer (due to the lower prices), produces more benefits than the central case.

Table 3.6: Present value of consumer surplus, 2005–09 (NZ$m)—range under specification

Option	Specification—low case			Specification—high case		
	Price effect	Take-up effect	Total	Price effect	Take-up effect	Total
1: Full	(91.7)	0.1	(91.5)	63.0	2.1	65.1
2: Line sharing	(9.0)	0.3	(8.7)	23.9	3.2	27.2
3: Bitstream	(15.9)	0.2	(15.7)	43.3	6.7	50.1
4: Fixed PDN	9.2		9.2	103.4		103.4

For the designation scenario, as expected, the low case (high prices) results in lower welfare benefits for Options 2 to 4, and the high case produces increased benefits. However, this does not appear to be the case for Option 1, where there are considerably lower benefits in the low case, but with significantly higher take-up benefits than the central case. In the high case there are greater benefits across the board.

As was noted for specification, these results are generated by the impact of voice subscribers. For the low case, the designated voice-only prices (P_1 and P_2) are above P_0, with the exception of P_2 for business. The additional revenue provided by these inelastic voice-only subscribers supports the unbundling of considerably more exchanges. As a result, more new data and voice subscribers take services (hence the higher take-up effect benefits), but all voice-only subscribers (including those of TCNZ that are charged the same higher prices) suffer a welfare loss. This latter effect outweighs the positive take-up benefits, and results in the substantial welfare loss.

Table 3.7: Present value of consumer surplus, 2005–09 (NZ$m)—range under designation

Option	Designation—low case			Designation—high case		
	Price effect	Take-up effect	Total	Price effect	Take-up effect	Total
1: Full	(89.6)	47.1	(42.5)	114.8	32.2	147.0
2: Line sharing	65.8	24.1	89.9	89.1	37.8	126.9
3: Bitstream	105.3	40.4	145.7	135.1	55.9	191.0
4: Fixed PDN	144.2		144.2	312.0		312.0

In the high case for Option 1 there are fewer ESAs being unbundled as a result of the lower revenues per subscriber (hence the reduction in the take-up effect), but the welfare benefits per subscriber are higher, also because of the lower prices. Overall, this results in greater welfare benefits.

The ranges illustrate the variability of the welfare outcomes around the prices used in the model. With the exception of Option 1, the model does not appear oversensitive to changes in these prices. However, voice services have a considerable impact on the welfare outcomes in Option 1.

3.1 Sensitivity analysis

As the model has been constructed to allow the key variables to be adjusted in each case, there are many potential sensitivity analyses that could be run. For this analysis, four sensitivities to the central case have been selected for the options:

Sensitivity 1 the WACC is set at 13%.
Sensitivity 2 the elasticity has been set to –1 (down from –1.5);
Sensitivity 3 the cut-off limit for feasible ADSL connections is reduced from 7km to 4km;
Sensitivity 4 the base case is re-run with high OSS costs included.

Sensitivities 2 and 3 are not relevant to the modelling of the unbundling of the fixed PDN. The results from these sensitivities are presented in Tables 3.8 to 3.11.

Table 3.8: Present value of consumer surplus, 2005–09 (NZ$m)—Sensitivity 1: WACC set to 13% (18% in central case)

Option	Specification			Designation		
	Price effect	Take-up effect	Total	Price effect	Take-up effect	Total
1: Full	(2.0)	0.7	(1.3)	66.7	46.4	113.1
2: Line sharing	6.4	0.4	6.8	92.2	36.7	128.9
3: Bitstream	12.9	1.0	13.9	126.5	50.7	177.2
4: Fixed PDN	57.1		57.1	235.7		235.7

Lowering the WACC has the effect of making entry more likely, and this is reflected in Options 2–4 by increased consumer welfare benefits. This is also the case in Option 1 for specification, but the ESAs that are unbundled have negative net welfare benefits as a result of P_1 being greater than P_0. Hence, the net outcome is a reduction in welfare compared with the central case.

Table 3.9: Present value of consumer surplus, 2005–09 (NZ$m)— Sensitivity 2: elasticity set to –1 (–1.5 in central case)

Option	Specification			Designation		
	Price effect	Take-up effect	Total	Price effect	Take-up effect	Total
1: Full	0.3	0.4	0.7	47.7	22.0	69.7
2: Line sharing	5.3	0.2	5.5	57.2	15.3	72.5
3: Bitstream	12.6	0.7	13.3	108.6	28.8	137.4

Reducing the elasticity lowers the number of new subscribers that take broadband services following the price falls, and thus has a most marked impact on the take-up effect component of the welfare calculation. However, the reduction in revenue generated from new subscribers has a knock-on effect on the viability of entry; this results in fewer ESAs being unbundled, and hence lower benefits overall.

Table 3.10: Present value of consumer surplus, 2005–09 (NZ$m)— Sensitivity 3: feasible ADSL connection distance set to 4km (7km in central case)

Option	Specification			Designation		
	Price effect	Take-up effect	Total	Price effect	Take-up effect	Total
1: Full	0.9	0.5	1.4	43.5	31.4	74.9
2: Line sharing	5.1	0.3	5.4	69.8	27.9	97.8
3: Bitstream	11.3	0.9	12.2	110.3	44.3	154.6

If the feasible distance for ADSL connections is reduced, the number of customers that can be served falls. As expected, this results in lower benefits across all the options.

Table 3.11: Present value of consumer surplus, 2005–09 (NZ$m)— Sensitivity 4: OSS costs set to 'high'

Option	Specification			Designation		
	Price effect	Take-up effect	Total	Price effect	Take-up effect	Total
1: Full	(27.7)	0.4	(27.3)	12.0	37.2	49.2
2: Line sharing	(1.0)	(0.03)	(1.0)	75.7	30.0	105.7
3: Bitstream	0.6	(0.06)	0.5	117.5	46.8	164.4
4: Fixed PDN	52.2		52.2	223.1		223.1

Increasing the costs of OSS results in higher prices, which generate lower welfare benefits in all the options and scenarios. As noted, the voice revenues are driving the results. The increased prices for voice-only customers stimulate an increased number of ESAs to be unbundled, but the unbundled voice prices are higher than P_0, resulting in a net welfare loss to all voice-only customers (including those of TCNZ). This, in turn, exceeds the positive benefits from lower data prices and generates much lower (negative) overall welfare benefits than in the central case.

The increase in voice revenues in designation, producing more unbundled ESAs, is also the cause of the increase in the take-up effect benefits in designation for Option 1. Again, the negative welfare benefits from voice reduce the positive benefits on the data side, which produces a lower welfare benefit overall, despite the greater level of market entry.

4. Model Structure

This section presents the structure of the model, and details how it determines the various outputs required to model the impact of regulation in the four options. Data used to populate the model is presented in section 5.

The only difference between the specification and designation cases is that, for designation, the wholesale access prices for unbundling may be set by the Commission (ie, they are regulated), should a determination be requested. There is no difference in the *structure* of the model between these two scenarios; the only changes are in the input costs and price data.

Furthermore, the components of full unbundling are data and voice services, while line sharing involves the provision of data only. Therefore, there is a high degree of commonality between these options on the data side. The primary difference is in the entry decision; for full unbundling, the entrant takes into account the costs and revenues of both data and voice (exploiting any economies of scope that exist), while, for line sharing, there are costs and revenue from data services only.

In the following sub-sections, the model approach outlined with regard to the data applies equally to full unbundling and line sharing. The NPV assessment of the entry decision and the consumer welfare calculations are addressed separately.

4.1 Counterfactual

The counterfactual sets out what might be expected to happen if LLU were not introduced. As noted, rather than the forecast that was used in the draft report, the final model formulation is designed so that the counterfactual approximates TCNZ's forecast of broadband take-up.

The importance of the counterfactual is that it provides the base case against which to measure the incremental benefits of LLU. All benefits accruing to subscribers are measured relative to the counterfactual, and, from an economics perspective, only those benefits over and above what would have occurred in the base case are important. Since the benefits forecast to accrue to consumers are measured by price reductions, the only difference between the counterfactual and each scenario is the effect of any price changes that result from regulatory intervention. These price reductions drive the take-up of services. In other words, the number of subscribers in the counterfactual is forecast using the same methodology as take-up in Options 1–3, minus the elasticity effect of the price change (as described in section 2.3.2).

There are two services in the counterfactual—data and voice—each provided to business and residential customers. The method by which the counterfactual numbers in the model are derived is outlined below.

4.1.1 Business and residential

TCNZ provided data on the current number of lines on an ESA basis, split between business and residential. It also provided data on the number of working ADSL ports, which were allocated to business and residential customers using the same proportion as the split for the lines.

4.1.2 Data subscribers

The number of data subscribers in the counterfactual was generated using the same methodology as described in section 2.3.2, with the parameters adjusted so that the predicted number of business subscribers approximated TCNZ's forecast profile.

4.1.3 Voice subscribers

As New Zealand already has a high level of voice telephony penetration, it was assumed that 100% of the lines detailed by TCNZ were used to provide voice services (excluding those used for non-PSTN services). Furthermore, given the existing high penetration level, it was assumed that there would be no further growth in the number of voice lines. This is a conservative assumption, as it is likely that new house-building and the growth of multiple lines for residential customers will increase the number of voice lines over the period.

4.1.4 Prices

It was assumed that prices would fall by 5% as a result of technological developments and the impact of the wholesale determination, leading to cost reductions for both voice and data services over the period of analysis. This applies to the data and voice monthly line-rental and service charges. The connection charges are held constant (in real terms over the period).

Data prices include the cost of the ISP for both business and residential customers since this is a real cost that the consumer must face, as discussed in section 2.4.[19]

4.2 DSL data unbundling

4.2.1 Business and residential customers

Business and residential customers on DSL data or bitstream services are served from the same ESA using the same equipment (eg, DSLAMs). There is no dedicated business or residential capacity other than the specific line running to the customer premises. Therefore, equipment resulting from an investment in upgrading an exchange can be used for either business or residential services, and the likely demand from both would be taken into account in making the unbundling decision.

As a result, the number of likely customers for each market segment must be calculated separately, but both should be included when assessing the entry decision. As the process for determining the likely take-up is the same for both groups, it is not explained separately below. However, the distinct business and residential data inputs are detailed in section 5.

[19] The new entrant may or may not provide ISP services itself (on an arm's-length basis). However, the cost will always form part of the consumption decision from the consumer's perspective (regardless of whether they are business or residential).

4.2.2 Technically upgradeable lines

The number of technically upgradeable lines is the starting point for the model, as an indication of the potential size of the market. As noted, the number of lines in each ESA that can be upgraded to DSL services will be reduced owing to certain technical constraints, including:

- distance from the exchange;
- transport technology (eg, PCM);
- existence of sub-loops;
- interference.

In practice, it was difficult to ascertain independently the coincidence of these factors without detailed and exhaustive engineering analysis of TCNZ's network. For example, some lines that are outside the requisite distance from the exchange may also be on a sub-loop or served by a PCM transport cable. Therefore, to apply these factors successively would understate the number of DSL-upgradeable lines.

As an alternative, OXERA obtained TCNZ's estimates of the number of upgradeable lines per ESA that it has used for its own engineering purposes. This information forms the basis for the number of lines available to entrants.

4.2.3 Price-determination mechanism

Section 2 discussed the likely impact of LLU on the price of voice and data services in New Zealand. In the ESAs in which entry occurs, it is assumed that there will be a price reduction, the extent of which depends on whether one or two firms enter.

For data services, under the specification scenario, there will be a negotiation between TCNZ and the entrant in order to determine the appropriate wholesale prices for unbundling; while, for designation, this will be established by the Commission if a party applies for a determination. The prices used in the model have therefore been developed on different bases for these two scenarios.

The objective in constructing the one- and two-entrant prices is to establish an approximate level for the prices in each scenario. In particular under designation, where a bottom-up approach is adopted, the intention is not to construct a precise cost-based price, such as a long-run incremental cost (LRIC) price. Rather, the aim is to estimate the market prices following unbundling. To this extent the price construction methodology adopted in specification and designation (top-down and bottom-up respectively) is merely a process to provide an indication of the level of the prices.

To this extent, it is not necessary to be precise in the construction of the bottom-up price in particular, as would be the case in generating a LRIC price. Provided the estimates used are reasonable, the resulting price will be a close approximation of the post-regulation price. As a result, it is not necessary to consider including within the price elements such as an explicit return on capital; the issue of the recovery of such costs is dealt with through the NPV calculation that drives the entry decision (as discussed below).

Specification

The prices under the specification scenario are the result of a top-down approach. The current TCNZ weighted average price for data services, including the ISP charge, is calculated as the starting point (the base price).[20] It is then assumed that, as a result of entry, TCNZ will be forced to become more productively efficient, and to lower its profit level.[21] This results in a profit and efficiency reduction to the base price. In addition, certain costs of LLU are incurred by both TCNZ and the entrant(s); namely the set-up of TCNZ's information systems and the regulatory costs of submissions.[22] As these are common to both TCNZ and the entrant(s), it is assumed that they will be recovered from consumers and are added back into the price.

The result of these adjustments is a retail price that is likely to decrease over time under full competition (two entrants). It is assumed that the full price adjustment does not occur in the first year, so a glide path is used, with the end price reached in the final year of modelling—year 5.

Where there is only one entrant, the full benefits of competition are not obtained, and the retail price in this case is assumed to be above the retail price for full competition. In the central case, the one-entrant price is 10% above that for full competition.

Designation

For the scenario of designation of wholesale prices by the Commission, a bottom-up approach is used to derive retail prices.

The regulated wholesale prices for Options 1 and 2 (full unbundling and line sharing) were based on recommendations by the Commission's consultants, Covec. The wholesale access charge for Option 3 (bitstream) was assumed to be the same as for line sharing, with an additional allowance for contribution to the cost of TCNZ's DSLAMs. In Option 4 (fixed PDN), a retail-minus-type approach is used to derive the wholesale costs.

The overall retail price for designation was derived by summing the wholesale cost with the other costs of entering the market, which were categorised into fixed costs, the set-up capital costs, and the variable costs per line. The one-off and fixed annual costs had to be converted into a charge per line. This was approximated by amortising the costs on a straight-line basis over a reasonable lifetime (either the asset lifetime or five years for unbundling set-up costs to reflect a likely entrant's time horizon). The costs were then divided by a suitable number of lines to determine the cost per line. The number of lines was determined by considering the average likely number of unbundled lines in the ESAs most likely to be unbundled, namely metro or urban exchanges. Further detail on this process is provided in section 5.

[20] The existing prices of the services are weighted by the proportion of subscribers taking each service.

[21] The estimate of this reduction in efficiency results from OXERA's efficiency analysis of TCNZ, see the accompanying paper, 'Estimating the Relative Efficiency of Telecom New Zealand'.

[22] The costs of regulatory submissions in the specification scenario are assumed to be half those of designation, as specification does not involve a price determination.

The objective of this process was to approximate the likely price level rather than to determine with accuracy a fully cost-reflective price. As a result, it was not necessary to include either a return on capital for specific assets, or on sales in general.

The removal of the return on sales element of the price (and by corollary from the costs in the NPV calculation) represents a significant change from the draft model. For the final model, the full process of the model was reconsidered, and it was recognised that it was unnecessary to have the return on sales allowance in the price because the entrants' revenues were already discounted by the WACC, hence ensuring that the cost of capital could be met.

As a return on sales measure is a proxy for the cost of capital where capital intensity is low, to incorporate both would result in double-counting of returns. Furthermore, it would artificially raise the post-unbundling prices to levels above where they may actually reside. A simple test of this argument is to consider whether entry occurs in any ESAs—if it does, there must be sufficient revenue for the entrant to cover its cost of capital, and prices have not been set too low.

4.2.4 Penetration of high-speed data services

To determine the number of customers that subscribe to high-speed data services, the model requires a measure of penetration which identifies the percentage of customers with upgradeable lines that actually subscribe to DSL. The base level of penetration in the counterfactual is determined by TCNZ's forecast demand, and this penetration is moderated by a price effect. The percentage expected overall price fall for the relevant scenario (derived from the price-determination formula above) is multiplied by an elasticity factor to obtain the adjusted penetration rate.

However, as described in section 2.3.2, it is assumed that neither the price reduction nor the increase in penetration occurs immediately. Instead, consumers' take-up of high-speed data services grows gradually over time as an increasing number of subscribers become used to broadband; this is represented by a take-up profile derived from the TCNZ forecast of future take-up. The take-up rate determines the percentage of the ultimate penetration that is achieved in each year, reaching 100% in the seventh or ninth years following upgrade for residential and business subscribers respectively, producing a level of penetration that applies to each year. The percentage penetration rate is applied to the number of upgradeable subscribers for each year in order to determine the number of subscribers interested in taking broadband services.

A significant number of ESAs have been upgraded already, and more will be upgraded before unbundling is introduced. For these ESAs, the model ascertains the year in which the upgrade took place (or is due to take place), and adjusts the forecast take-up rate to match that used with the correct year following upgrade in the take-up profile. This ensures that the forecast number of subscribers is appropriate to the circumstances of individual exchanges.

An additional adjustment is made to account for the number of potential subscribers that choose to use alternative technologies. The number of upgradeable lines multiplied by the penetration rate gives the number of subscribers interested in broadband per se, but not necessarily in DSL. Alternative technologies, such as cable or wireless, can also deliver high-speed data products, so the number of potential subscribers is reduced by a percentage to represent the net churn to different infrastructures.[23]

Resulting from these calculations is a forecast number of DSL subscribers for each year. These are split between business and residential users on the basis of the proportion of business and residential customers in 2003.

4.2.5 Apportionment of subscribers between TCNZ and entrant(s)

To determine the number of subscribers that a new entrant would gain, it is necessary to apportion the forecast business or residential subscribers between the entrant(s) and TCNZ. This is achieved through the use of churn rates and competition for new subscribers.

The entrant acquires subscribers from TCNZ on the basis of a net churn factor that also takes into account any TCNZ win-back from the entrant.[24] The churn rate is applied to TCNZ's installed base at the end of the previous year to determine the number of subscribers switching to the entrant during that year.

New subscribers are apportioned between TCNZ and the entrant(s) on the basis of a competitive acquisition factor that is weighted towards TCNZ, reflecting its favourable position as the incumbent. In each year the residual of the total forecast subscribers less TCNZ's existing installed base is allocated on the basis of the competitive acquisition factor. Therefore, at the end of each year, TCNZ's number of subscribers for the start of the next year is determined as its subscribers at the start of the year minus those lost through churn to the entrant(s), plus the new subscribers won in competition in the market. Similarly, the entrant's subscribers are the start number plus gains from churn and competition.

4.2.6 Economic feasibility test for entry

The entry decision is addressed at the ESA level, and firms decide to enter on the basis of the NPV of the relevant costs and revenues for that ESA. The revenues are a product of the prices detailed above, multiplied by the number of subscribers, where relevant. The costs are a combination of one-off set-up costs per ESA, one-off per-subscriber

[23] The use of a net churn figure accounts for the fact that TCNZ and/or the entrant(s) may also gain existing customers back from other technologies in each year.

[24] Implicit in this is an assumption that there will be net churn towards the entrant. This reflects what has happened in the course of competition between TCNZ and TelstraClear.

connection costs (incurred as subscribers join), and monthly per-subscriber fees. The costs used in the model, and their derivation, are considered in more detail in section 5.

The discount rate used in the NPV calculation is the relevant WACC. This ensures that the entrant earns an adequate return in order for entry to occur. If the NPV calculation is negative, this implies that the total revenues net of costs would be insufficient to allow the entrant a sufficient return on its investment, and entry would not occur.

In considering the submissions on the draft model, it was clear that the draft model was forcing the entrant to meet a higher profit hurdle than required in order to enter. The inclusion of the WACC as the discount factor on the NPV ensures that the entrant is earning its cost of capital before it enters—if the discounted returns are not sufficient, the NPV calculation will be negative and entry will not occur. It is therefore not necessary to include a return on sales element in the costs required to be covered in the NPV calculation, as this factor (an adequate return for the entrant) has already been taken into account through the discount rate. Accordingly, this has been removed from the cost side of the NPV calculation.

The model runs the entry decision twice in order to determine how many entrants provide unbundled services. The sequential logic is as follows.

- *Will one firm enter?* The model calculates the NPV given the number of subscribers at a price denoted P_1, using the churn and competitive acquisition rates, and the relevant costs. P_1 is above the fully competitive price.

- *Will two firms enter?* This model run halves the number of subscribers available to each entrant, assuming that they will be shared equally between them, and determines the NPV as before, using a price denoted P_2, where this is the fully competitive price.

Entry only occurs when the NPV calculated is positive. If only one firm enters, prices are assumed to fall, but not to fully competitive levels. If two firms enter, then full competition would ensue.

The churn rate towards the entrants does not increase as a result of two (or more) firms entering, as compared with the situation with one entrant—ie, between the one- and two-entrant outcomes in the model. This is likely to understate the actual market reaction, as two or more entrants would be likely to stimulate greater aggregate churn than one entrant, and thus this assumption reduces the likelihood of entry in the model as compared with reality.

For line sharing, the entrant supplies only data services, and the above analysis applies exactly. However, it is slightly different for full unbundling. In the full unbundling option, the NPV is determined on the basis of the sum of the revenues from data and voice services, and the costs are those relating to voice and data services provision. These include costs common to data and voice, as well as costs related to the separate provision of the services. It is assumed that the entrant is able to take advantage of any economies of scope between voice and data in providing the unbundled exchange.

4.2.7 Consumer welfare calculation

The estimation of consumer welfare is the principal output from the model, and is derived from the modelling process outlined above. As discussed in section 2.6, two main forms of benefit apply to consumers: price effect and take-up effect. The process by which each is calculated in the model is considered below. However, in the welfare context, the definition of 'consumers' is broad, and includes all subscribers to voice and data services affected by changes resulting from unbundling. This implies that the benefits to both business and residential users are taken into account and weighted equally in the consumer welfare calculation. Such an assumption is in accord with the Telecommunications Act, which refers to 'end users' of telecommunications services, which are likely to be both residential and business customers.

The consumer welfare benefit is calculated for each year in each ESA. As noted, where there is no entry, there is assumed to be no welfare benefit, as prices do not change in the central case.

Price effect

For each ESA, the model predicts the number of subscribers taking data services in each scenario (ie, specification and designation) for the years that are modelled. The counterfactual provides the annual number of subscribers that would have been receiving data services without unbundling. It is this latter group that receives the price benefits.

The extent of the price benefit per subscriber is calculated as the difference between the counterfactual price and the scenario price, given the number of entrants, for the ESA in the relevant year. In the draft model, it was assumed that, where there is only one entrant, TCNZ would not fully meet the entrant's price. However, as detailed above, this assumption has been revised for the final model and TCNZ is assumed to meet the new entrant's price exactly.

Take-up effect

Those subscribers that would not have taken data services were it not for the price falls gain a welfare benefit equivalent to the difference between their willingness to pay and the price they actually paid. The model calculates this effect by taking the difference between the counterfactual and scenario prices multiplied by the number of affected subscribers, divided by two. While this is a necessarily simplistic estimate, it would underestimate the size of the take-up effect, and is thus a conservative approach. A linear demand curve has been implicitly assumed in making this calculation. However, as detailed in section 2.6, it is anticipated that the results would not have been significantly different had a compensated demand curve been used.

The total consumer surplus from unbundling data services (Option 2) is the sum of the price and take-up effect estimates, while, for Option 1, the welfare benefits of voice unbundling are added to these benefits from data.

4.3 Voice unbundling

For the reasons discussed in section 2, it is assumed that voice services are only unbundled when an entrant is offering full unbundling; they do not unbundle in order to provide local calls and access services alone. This sub-section outlines how the model calculates the benefits to consumers from the unbundling of voice in the full unbundling option (Option 1).

4.3.1 Number of subscribers

The number of voice subscribers is determined by the number of TCNZ subscribers in 2003. This assumes that there is close to 100% voice penetration, and the number of households or lines does not grow significantly over the period.

It is reasonable to assume that all subscribers with lines take voice services. The assumption of no market growth over the period of analysis is conservative and may understate the benefits to consumers.

4.3.2 Price of voice services

The derivation of voice services in the specification scenario is the same as for data services. That is, the existing TCNZ retail price is used as a starting point and adjusted for an improvement in allocative efficiency (reduced profitability), productive efficiency, and an increase in costs due to the common costs of LLU. Furthermore, as with data services, the one-entrant price is assumed to be 10% above the fully competitive price.

In this case, however, it is assumed that there is both a stand-alone voice product and a bundled voice and data product. TCNZ has recently withdrawn its bundled voice and data product, so the bundled price was generated from summing the stand-alone voice and data prices.

There are few wholesale elements that would need to be purchased from TCNZ in order to provide unbundled voice services, and there are economies of scope in the unbundled line-rental charge (with data services). Therefore, it is assumed that there is no difference between the retail prices for unbundled voice services under specification and those under designation.

4.3.3 Levels of switching

Given the absence of market or subscriber growth, the only way in which the entrant gains subscribers is by churn from TCNZ. Therefore, a net churn factor is applied to the number of TCNZ subscribers each year to determine the number of subscribers switching to the entrants.

As outlined at the beginning of this section, some subscribers receive voice-only services from an entrant offering full unbundling. This is addressed in the model by estimating the number of subscribers that will switch to voice services, regardless of whether they also take data services. The number of voice-only subscribers can then be calculated as the difference between the total number of voice switchers, and those taking data services. Within the model, however, subscribers to voice services are treated as a single block, separate from data subscribers (except for the entry decision, as discussed below).[25]

[25] As a result of this approach, both the prices and costs for data are treated as incremental to the voice revenues and costs in order to ensure that they are not double-counted in the modelling.

4.3.4 Entry decision

The process by which the entry decision is modelled is the same as for DSL data unbundling described above. However, as noted in section 4.2.6, the decision to enter for voice services is a joint one with that for data services, and the costs and revenues are pooled in order to determine whether full, unbundled entry is commercially viable.

4.3.5 Welfare calculation

As there are no new subscribers, only existing subscribers gain a price benefit. This is calculated as in section 4.2.7, taking the price reduction multiplied by the number of consumers that benefit from it.

This benefit is added to the benefit from unbundled data services subscribers in order to determine the total welfare benefit of full unbundling (Option 1).

4.4 Bitstream access

Bitstream access provides a *service*-level entry to DSL data provision. The entrant buys the complete service for a high-speed (eg, 2 Mbps) link to the consumer, and the service includes delivery to the first data switch in TCNZ's network. The entrant would need to arrange backhaul to its own network from this point.

The entrant is therefore bound by TCNZ and its investment plans because the high-speed link will only be available at exchanges that TCNZ has already upgraded. The entrant cannot upgrade an exchange itself through bitstream access.

Bitstream access enables the entrant to provide high-speed data services to residential or business customers, which is the same outcome as DSL data services unbundling, albeit via a different technical solution. Therefore, it is assumed in the model that the retail products and corresponding prices are the same as for DSL data services (specifically those for line sharing, Option 2).

4.4.1 Availability of bitstream access

Bitstream services can only be obtained where TCNZ has already upgraded the exchange, so the potential subscribers available to the entrant are limited to those within these exchanges. Once an exchange has been upgraded, TCNZ has indicated that some marginal investment may be required in order to expand the number of DSL lines that can be provided, but an allowance is made in the costs to cover TCNZ's DSLAM costs (including a return on capital). Hence, the actual number of lines per exchange is not a restricting factor, as the capacity can be expanded to meet demand.

TCNZ also supplied to the Commission its plans for upgrading ESAs over the next few years, but the scheduling of this investment by year was not detailed. For the purposes of modelling, it has been assumed that an equal number of exchanges was upgraded in each of the three years of the upgrade plans (ie, the total number of planned upgraded ESAs over the next three years was divided by three to obtain the annual number of upgrades). Furthermore, it has been assumed that the exchanges were upgraded in order of size, with the largest upgraded first. This provided the number of exchanges, and hence subscribers, that could be accessed by bitstream services. It was assumed that no exchanges were upgraded beyond those in TCNZ's plans, which may reduce the total number of lines available for bitstream access, and hence underestimate the potential consumer benefits.

4.4.2 Price

The retail services being delivered through bitstream access are the same as those for DSL data; the DSL data retail prices (Option 2) are therefore applied to the bitstream services under specification.

Under designation, the prices are built up in the same way as for Options 1 and 2, but some different costs are incurred.

4.4.3 Entrant subscribers

Although the entrant does not upgrade new exchanges, it can expand the market by competing on price (or, in future, on the bundle of services it offers, as discussed in section 2.2). Thus, the entrant gains existing subscribers from TCNZ, or competes with TCNZ for new subscribers as they take broadband services.

The number of new subscribers in each year (in the TCNZ-upgraded exchanges) is determined in the same way as for DSL data above, as is the apportionment between TCNZ and the entrant for churn and competitive acquisition.

These calculations give the number of subscribers that take bitstream access services from the entrant.

4.4.4 Entry decision

The entry decision is also modelled in the same way as for DSL data, using the revenues from subscribers and the costs specific to bitstream access.

4.4.5 Welfare calculation

In line with the DSL data welfare calculation, there is a price and take-up effect for existing and new subscribers, respectively. Although the subscribers that are predicted in the counterfactual to take broadband would not be receiving their services through bitstream access, the *product(s)* they receive would be identical. Therefore, the consumer is ambivalent regarding the technology used to deliver its services, and all that matters is the relative price. To the consumer, the delivery of services by TCNZ or a bitstream access operator would appear the same.

4.5 Fixed PDN

The fixed PDN consists of a set of dedicated data access lines running to customers' premises. Each access line comprises two twisted copper pairs: one provides an upstream connection; the other a downstream connection. As the copper is dedicated to data, consumers need a separate voice line, and the fixed PDN connections are installed as required, rather than being readily available should a customer decide to subscribe. For these reasons, the fixed PDN is assumed to be a business, rather than a residential, service.

4.5.1 Potential subscribers

The number of potential subscribers to fixed PDN services is limited to the number of existing data tails in TCNZ's network because the entrant unbundles the existing infrastructure and does not install new connections.

4.5.2 Pricing

The services delivered by the fixed PDN are numerous and varied. For example, it is possible to provide high-speed Internet access, as with ordinary DSL connections. However, the fixed PDN could also be used by customers to transmit low-level automated data, such as stock-replenishment systems in supermarkets. It is therefore difficult to identify a single, or even representative, service that is delivered over the fixed PDN. In consultation with the Commission staff, OXERA considered two products: Frame Relay and DDS. Prices for the representative product used in the modelling were based on an average of prices for sample customers (see section 5).

4.5.3 Entrant subscriber acquisition

As the entrant does not expand the number of fixed PDN connections, the subscriber growth is limited to churning existing fixed PDN subscribers away from TCNZ's services.

4.5.4 Entry decision

In the same way as for the other forms of unbundling, the entrant will decide whether to unbundle a particular exchange on the basis of the relative discounted costs they would incur and revenues they would acquire. However, because of the lack of definition regarding the representative product, it is difficult to match underlying costs with services. A top-down approach is therefore adopted for the pricing in both specification and designation; the prices in designation are assumed to be a proportion of the specification prices.

As in the other options, the model cycles through the prices for one and then two entrants in order to determine the appropriate level of entry. The outputs from this are the identity of the exchanges where unbundling of the fixed PDN occurs, the number of entrants, and thus the number of lines that are affected.

4.5.5 Consumer welfare analysis

The entrant is only taking demand away from TCNZ, so the welfare calculation consists solely of a price effect. Those subscribers that take data services from the entrant following unbundling benefit from a lower price. Therefore, the welfare benefit equates to the number of subscribers affected, multiplied by the price fall compared with the counterfactual.

4.6 Impacts of other regulatory decisions

4.6.1 Number portability

As of December 2003, New Zealand does not have a direct number portability scheme that would allow customers to retain their existing telephone number when they move house.[26] It is anticipated that such a scheme will be introduced in the foreseeable future.

The impact of a number portability system would be to increase the likelihood of consumers switching suppliers, as the switching costs are reduced. It has been identified in both mobile and fixed-line markets that the need to change telephone number can significantly inhibit switching behaviour.[27]

In terms of the modelling, the introduction of number portability could be accommodated through an adjustment of the churn rate in the full unbundling scenario to take into account the anticipated higher switching rate. As the other forms of unbundling relate to data rather than voice services, number portability is not relevant.

4.6.2 Wholesale decision

Following a determination by the Commission, TCNZ is supplying a range of data and voice products to other carriers. The wholesale price is calculated on a retail-minus basis using 16%. This could alter entrants' decisions over which regulatory route to use to supply consumers through purchase of wholesale services from TCNZ, or LLU.

The wholesale determination is likely to encourage more entry, and thus have a downward effect on retail prices. Following discussions with the Commission, it was determined that a combination of the wholesale decision and technological advances leading to reduced costs would be likely to generate price falls of 5% up to 2009 in Options 1–3, and 3% in Option 4.

[26] There is an indirect process where the number remains with the initial provider and calls are then forwarded to the appropriate service provider, but this is an unwieldy and inefficient method of achieving number portability.

[27] Monopolies and Mergers Commission (1995), 'Telephone Number Portability: A Report on a Reference under Section 13 of the Telecommunications Act 1984', December.

5. Data Employed

This section sets out the data used in the model, and how prices and costs have been derived for the counterfactual and the options.

As discussed, the test for whether firms enter the market is based on an NPV analysis of the expected revenues and costs. The revenues are built up from the appropriate price multiplied by the number of subscribers.[28] The stream of net revenues is then discounted at a pre-tax cost of capital of 18% (decided in conjunction with the Commission—see the Commission's final report), to result in an entry decision. Where there is entry, the welfare calculation takes into account the increase in the number of subscribers over the counterfactual and the prevailing prices. This results in the consumer surplus measurement.

The number of subscribers is described in section 5.1. Prices are outlined in sections 5.2 (counterfactual prices); 5.3 (specified prices); and 5.4 (designated prices). The relevant costs—or, as referred to in subsequent sections, the 'cost side'—are also discussed in section 5.4, alongside the development of the designated prices. These prices and the costs are closely linked, given the cost-based approach to designated prices.

One major difference between the options is the inclusion of voice in Option 1. For simplicity in the model, the numbers of subscribers for voice and data are forecast as separate populations, although it is assumed that there is a complete overlap. There may be voice subscribers in addition to the number of data subscribers,[29] in which case it is assumed that these customers take voice services only.

To cope with this in the model, in terms of costs and revenues, the per-line costs and revenues for data subscribers are included as incremental to the per-line costs and revenues included for voice subscribers. In this way, the correct level of revenue and cost is assigned both to subscribers that take the combined package and to those that take voice services only. In the derivation of prices, this means that the data-only prices (and therefore) revenues included are the difference between the price for the bundled product and the voice-only product. Similarly, on the cost side, only incremental per-line data costs (eg, the ISP charge) are included.

The fixed PDN has also been modelled slightly differently. The entry decision is based on the same NPV calculation as described for the other options, using the same discount rate. For the costs, it is assumed that the data services to be provided over the fixed PDN have a speed of up to 2 Mbps, as these could be supplied over copper circuits. For services over 2 Mbps, different technology, such as radio or fibre, would be required.

[28] GST is removed from residential revenues.
[29] By construction, the number of data subscribers cannot exceed the number of voice subscribers.

The available information on the costs underlying the provision of services over the fixed PDN is limited. Assumptions have been made, based on experience from other jurisdictions. As noted, it is assumed that an entrant would provide such services only over existing data tails, and therefore would incur the costs of unbundling, rather than those of installing the data tails. The different cost components were calculated for the sample customer specification **[✂] TDR**. These costs were then converted into cost per exchange/tail. The cost categories considered are examined below.

5.1 Modelling assumptions

5.1.1 Forecasting business and residential data subscribers

The important measurement in the model is the incremental change over the counterfactual that results from each unbundling option. Hence, the first step is to forecast take-up in the counterfactual. The second step is to forecast take-up in each option. The difference between the two is driven by the price change on unbundling, which drives increased take-up through an elasticity effect.

The third step is the welfare calculation, where the price and new subscriber aspects of the welfare effects are calculated based on the subscriber numbers derived. The calculation is done in each year, using the prevailing P_0 in that year (ie, allowing for adjustment for the reduction in ISP charge and price drop due to cost pressures), and the appropriate entry price (ie, P_1 or P_2) in that year, which in each year will be moving closer (along its glide path) to the final price. The welfare benefits are discounted at a rate of approximately 6%, this being the yield on New Zealand government bonds.

Counterfactual forecast

As noted in section 2, the Commission requested that OXERA adjust the penetration and take-up profiles for the counterfactual so that the forecast number of subscribers approximates TCNZ's forecast levels of take-up. The counterfactual forecast of business and residential customers has therefore been derived from information provided by TCNZ. The starting point for this forecast is the end of 2003, which has been interpolated from TCNZ's mid-2002 and mid-2003 figures. This represents a change from the position in the draft paper presented prior to the Conference.

The forecast of subscribers used in the counterfactual is shown in Table 5.1, together with TCNZ's forward view (derived using information provided for this investigation).

Table 5.1: Forecast of DSL subscribers in the counterfactual (000s)

	2004	2005	2006	2007	2008	2009	2010
Residential	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR
TCNZ Residential	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR
Business	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR
TCNZ Business	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR
Total	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR
TCNZ total	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR	[✂] TDR

Source: OXERA calculations.

Forecasts for Options 1 and 2

The number of subscribers per ESA per year for data services in the options is determined as follows:

Number of subscribers = price change × price elasticity × penetration rate × take-up rate × (1 – competing technology churn) × number of available lines

The relevant **price change** is between P_0 and P_1 for one-firm entry, and between P_0 and P_2 for two-firm entry.

Starting P_0 is used (ie, before the price drop for cost pressure has been factored in), and compared with either P_1 or P_2 in year 5. For consistency, P_1 and P_2 are also used at a level that does not include the price drop due to cost pressure.

As specific **price elasticities** for New Zealand were not available, information was sought on evidence of elasticity calculations in other countries for the take-up of high-speed data services. Table 5.2 summarises the papers identified.

Table 5.2: Academic research on high-speed data price elasticities

Demand price elasticity for high-speed residential cable–modem Internet access between –1.08 and –1.79	Kridel, Rappoport and Taylor (2000)
Point demand price elasticity for residential broadband in the USA between –2.15 and –3.76.	Goolsbee (2001)
Own-price demand elasticity (DSL): –1.18	Crandall, Sidak and Singer (2002)
Own-price demand elasticity (cable modem): –1.22	
Own-price elasticity for broadband Internet access: at least –2	BT (2003)
Own-price demand elasticity (DSL): –1.46	Telecommunications Research Group, Colorado University (2002)
Own-price demand elasticity (cable): –0.59	
Own-price demand elasticity (broadband) between –1.3 and –3.1 (based on experiment)	Varian (2002)

Sources: Kridel, D., Rappoport, P. and Taylor, L. (2000), 'The Demand for High-Speed Access to the Internet: The Case of Cable Modems', 13th Biennial Conference of the International Telecommunications Society. Goolsbee, A. (2001), 'Subsidies, The Value of Broadband, and The Importance of Fixed Costs', GSB University of Chicago. Crandall, R., Sidak, J.G. and Singer, H. (2001), 'The Empirical Case Against Asymmetric Regulation of Broadband Internet Access', *Berkeley Technology Law Journal*, **17**:3. BT (2003), 'BT's Response to Oftel's Consultation Document "Review of the Wholesale Broadband Access Market"', July 7th. Telecommunications Research Group (2002), 'Broadband Demand Study: Final Report', University of Colorado at Boulder, November 15th. Varian, H. (2002), 'The Demand for Bandwidth: Evidence from the INDEX Project', University of California at Berkeley.

The estimate used in the model was an elasticity of –1.5 in the central case. As can be seen from the table, this is a reasonably conservative approach, as the range of industry elasticities is from –1.08 to –3.1, and there are a number of studies reporting figures of around –1.5.

The overall level to which demand will ultimately rise, given a particular price and sufficient time for consumers to adopt the new services, is referred to as the **penetration rate**. Ideally, this level should be identified through the use of detailed consumer survey information. TCNZ was unable to provide OXERA with this information. The penetration rate was adjusted in order to approximate TCNZ's forecast of broadband subscribers in the counterfactual.

As with the penetration rate, the **take-up rate** for residential and business subscribers was adjusted in order to approximate TCNZ's forecast broadband subscription levels in the counterfactual.

The above calculation results in an estimation of the number of subscribers that are likely to take high-speed data services, although not all of these will choose ADSL technology. The model therefore allows for a proportion of subscribers to choose to take their services from alternative infrastructures (mainly cable, satellite or wireless). The relevant parameter is the **competing technology churn** rate.

There are drawbacks with satellite and wireless which suggest that these infrastructures may not be direct substitutes for the fixed wireline. Nonetheless, consumers do currently switch from TCNZ to these different networks and are likely to continue to do so in future as new technologies improve and are able to make their services more widely available. Wireless broadband services from companies such as Woosh may provide an alternative to DSL broadband going forward, although there is no certainty of this. Therefore, the competing technology churn factor has been set at 5%.

Take-up within any ESA is naturally limited by the number of lines that are **technically available** for DSL. The basis for the number of technically upgradeable lines in each ESA is information supplied by TCNZ, which provided information on the number of business and residential circuit ends.[30] TCNZ has defined lines in range as those that meet its deployment criteria for DSL.[31] This includes lines up to 7km, but only at a rate of 500 Kbps. The model allows this distance to be reduced, and so lowers the number of lines in range. This calculation uses teledensity information supplied by TCNZ.[32]

Forecast for Option 3

The methodology for forecasting subscribers under Option 3 (bitstream unbundling) is the same as described previously, although it is assumed that bitstream services will only be available where TCNZ has upgraded an exchange (ie, installed a DSLAM), or has indicated that it intends to do so. TCNZ provided details of ESAs expected to be upgraded by 2006. For the CBA, it was assumed that these would be upgraded in descending order of size and that a third would be completed in each of 2004, 2005 and 2006.

Forecast for Option 4

It is assumed that the number of potential subscribers to the fixed PDN stays flat. The total number of subscribers to the fixed PDN is taken to be 'Non-PSTN' lines, as supplied

30 Data received from TCNZ, July 9th 2003.
31 Data received from TCNZ, July 9th 2003.
32 Data received from TCNZ, July 16th 2003.

by TCNZ.[33] The entrant will only be able to acquire customers that are already subscribing to TCNZ services, as these are the only customers with appropriate data tails.

5.1.2 Apportionment of data subscribers between TCNZ and entrants

The methodology described in the previous section results in a forecast of the entire DSL market going forward. For a new entrant to consider entering the market to provide high-speed Internet services over unbundled loops, it must be able to gain new subscribers from this market.

New entrants gain subscribers in the model in two ways: through churn from TCNZ; and through competition with TCNZ for new subscribers.

The churn rate used in the model is a blended rate between business and residential, and is set at 5%. This is a net churn rate, which means that it takes account of both churn from TCNZ, and win-back by TCNZ from the entrant. The 5% figure is derived from the experience of competition between TCNZ and TelstraClear in Wellington and Christchurch. It also seems reasonable in light of information supplied by TelstraClear at the Conference, indicating churn rates of up to 18%.[34]

The competitive acquisition rate is 25%, which implies that entrants gain 25% of all new subscribers, with the remainder going to TCNZ. This is less than 50% market sharing, as might be expected in a fully competitive situation, recognising that TCNZ is likely to retain an element of consumer loyalty, despite the market liberalisation.

For Option 4 (fixed PDN), the forecast of subscribers an entrant may be able to attract is calculated as a net churn from TCNZ’s subscriber base. In consultation with the Commission, the rate was set at 5%.

5.1.3 Voice subscribers

The number of voice subscribers is relevant only to Option 1 (full unbundling), where the entrant must offer a bundled product, or voice-only services.

The number of voice subscribers in the counterfactual is assumed to remain flat, and corresponds to the PSTN circuit ends supplied by TCNZ.[35]

Entrants are assumed to win voice subscribers away from TCNZ using a net churn rate of 5%. This is a blended rate that applies to both business and residential customers.

[33] Data received from TCNZ, July 9th 2003.
[34] TelstraClear (2003), ‘Annexure 1—TelstraClear LLU & Bitstream Business Case’, October 29th. It was unclear whether these were net churn figures.
[35] Data received from TCNZ, July 9th 2003.

5.1.4 ISP charges

In the residential counterfactual, the ISP charges are calculated in the same way as the retail prices—ie, as a weighted average of the ISP charges faced by customers. This results in an ISP charge of NZ$385 per customer.

By the end of the period of analysis (2009), it is assumed in the counterfactual that most customers will have taken higher-bandwidth products which attract lower ISP charges. As a result, the ISP charge becomes NZ$180 by year 5 (2009). In both specification and designation, it is assumed that competition results in a faster migration to higher-speed packages, and therefore all consumers only incur ISP charges of NZ$120 per year (NZ$10 per month).

In the options, the lower ISP charge is incorporated into P_1 and P_2, but the price is not assumed to reach these levels until the fifth year after unbundling due to the price glide path. Therefore, by implication, the ISP charge itself does not fall immediately to NZ$120, but gradually over the period of analysis.

5.2 Price derivation and price levels in the counterfactual

Retail prices in the counterfactual are assumed to be the same as those currently charged by TCNZ. These prices (P_0) form the basis against which consumer surplus changes resulting from regulatory intervention are measured. The model makes a distinction between residential and business customers.

TCNZ offers many and varied service packages, therefore, for model tractability, 'representative' products and prices are needed in the counterfactual. The representative products required for each option are:

- Option 1 (full unbundling)—this requires a representative bundled voice *and* data product for both business and residential customers. The product is derived as the summation of separate voice and data products. In the case of residential products, this is because TCNZ no longer offers a bundled voice and data product.[36] For the business sector, no information was available on the pricing of bundled voice and data business products, as these are determined by commercial agreements with TCNZ on an individual basis;
- Options 2–3—these require a data product for both business and residential segments (this is the same data product as derived for Option 1);
- Option 4 (fixed PDN)—this requires a comparative data product for the business segment only.

Further, as described previously, prices in the counterfactual are assumed to fall by 5% (Options 1–3) or by 3% (Option 4) over the life of the analysis, to reflect competitive and

[36] As of October 2003, TCNZ only offers a triple-play bundle, which incorporates Sky TV as well.

other downward pressures on cost.[37] In the case of data products in the residential sector, there is a further downward adjustment to reflect the contribution to the ISP charge over time. This is discussed further below.

5.2.1 Counterfactual products and prices for Options 1–3

Table 5.3 shows some of the packages offered to residential customers by TCNZ, including the calls and access voice product and HomeLine. For high-speed Internet products, it shows the monthly charge currently payable to TCNZ and the up-front connection charge. It does not show the cost of any modem needed, nor does it show any charges payable to an ISP where the DSL services are accessed via an ISP other than Xtra. TCNZ now includes this in the overall charge, rather than stating it separately.

However, ISPs, such as ihug, are currently charging NZ$10[38] per month for access to all their residential ADSL Internet options, except for the Starter pack, which is NZ$29.95.[39] The total cost to the consumer of using ihug to access the Internet is equivalent to the cost of accessing the Internet through Xtra.

Table 5.3: Some of TCNZ's residential packages

Product	Description (speed/traffic limit)	Monthly charge (NZ$, incl. GST)	Connection charge (NZ$, incl. GST)
Voice			
HomeLine	Unlimited local calls	39.3	38
Data			
Jetstream Home 1000 Full Speed	2 Mbps/1 Gbps	79.0	99–248
Jetstream Home 500 Full Speed	2 Mbps/500 Mbps	59.0	99–248
Jetstream Starter Access	128 Kbps/unlimited	64.9	99–248

Source: TCNZ's website, accessed December 9th 2003, and data received from TCNZ, July 16th 2003.

Tables 5.4 shows some of the packages offered to business customers by TCNZ. ISP charges are included separately in this table as the monthly charge payable to TCNZ does not include this charge. Again, the cost of modems is not shown.

The basic business access product for voice, Business Line, does not include local calling. Local calling at 4.55 cents per minute is therefore also assumed.

[37] As discussed elsewhere, this fall in prices is mirrored in the unbundling options to reflect the fact that the same pressures would be evident.

[38] Previously NZ$20, and included at this level in the draft paper.

[39] Previously NZ$34.95, and included at this level in the draft paper.

Table 5.4: TCNZ's business packages

Product	Description (traffic limit)	Monthly charge (NZ$, excl. GST)	ISP charge (NZ$, excl. GST)	Connection charge (NZ$, excl. GST)
Voice				
Local calling		4.55¢/min	–	–
Business Line		58.42	17.78	55.00
Data				
Jetstream 600	600 MB	61.33	17.78	80–220
Jetstream 1200	1.2 GB	120	17.78	80–220
Jetstream 1800	1.8 GB	176	17.78	80–220
Jetstream 3000	3 GB	292	17.78	80–220
Jetstream 5000	5 GB	458	17.78	80–220
Jetstream 10000	10 GB	888	17.78	80–220
Jetstream 20000	20 GB	1600	17.78	80–220

Source: TCNZ's website, accessed August 11th 2003, and data received from TCNZ, July 16th 2003.

The representative voice product for residential users (for Option 1) is assumed to be the HomeLine voice product, which includes free local calling and access for NZ$39.30 per month (including GST). The representative voice product for business users assumes a standard NZ$0.0455 per minute for local calling. Based on information in TCNZ's annual report, an average annual spend of NZ$285 (excluding GST) per business customer is included.

Appropriate representative data prices for both business and residential customers have been calculated using an average of the prices of the different packages (including the cost of the ISP), weighted by the proportion of customers currently subscribing to each package. The weights used are presented in Table 5.5.

**Table 5.5: TCNZ's residential and business packages—
proportion of customers (%)**

Product	Weights
Residential packages	
Data	
Jetstream Home 1000 Access	[✂] TDR
Jetstream Home 500 Access	[✂] TDR
Jetstream Starter Access	[✂] TDR
Business packages	
Data	
Jetstream 600	[✂] TDR
Jetstream 1200	[✂] TDR
Jetstream 1800	[✂] TDR
Jetstream 3000	[✂] TDR
Jetstream 5000	[✂] TDR
Jetstream 10000	[✂] TDR
Jetstream 20000	[✂] TDR

Source: Data received from TCNZ, August 12th 2003.

A weighted contribution to the costs of the ISP is also included in the counterfactual price for the residential data product. Over the course of the CBA, this element is expected to fall to reflect the fact that, as consumers become more aware of broadband products, they may start to upgrade and buy more sophisticated packages. This would imply a reduction in ISP charges, so the contribution of ISP charges falls from NZ$29 to NZ$15 per month, where this ISP charge is a representative charge that reflects the different packages available. This results in a counterfactual price at the end of the CBA that is considerably lower than the starting price level.

The level of ISP charge is not expected to fall to NZ$10 per month as in the options. This reflects an expected difference in the level of learning and awareness between the counterfactual and unbundling options—unbundling is expected to result in more competition and therefore greater efforts to make consumers aware of the product and its benefits.

The resulting representative prices for Option 1 (bundled voice and data) and Options 2–3 (data only) for both business and residential customers are shown in Table 5.6. Counterfactual starting and ending (ie, year 5) prices are shown. The final P_0 is achieved over the life of the CBA, as prices move down a glide path.

Table 5.6: Retail prices (NZ$) for residential and business customers in the counterfactual

Service	Residential customers[1]		Business customers[2]	
	Starting P_0	P_0—year 5	Starting P_0	P_0—year 5
Option 1				
Voice	472	448	986	937
Data	783	596	1,428	1,368
Combined	1,255	1,044	2,414	2,304
Options 2 and 3	783	596	1,428	1,368

Note: [1] Inclusive of GST and ISP charges. Prices exclude other charges such as modems and filters; connection charges not shown. [2] Exclusive of GST; inclusive of ISP charges. Prices exclude other charges such as modems and filters; connection charges not shown.
Source: OXERA calculations; TCNZ website.

5.2.2 Counterfactual prices in Option 4

As mentioned previously, it is difficult to identify a single, or even representative, service that is delivered over the fixed PDN. This is because the types of service that can be provided differ significantly, with important price variations between products. The pricing structure generally includes an installation charge and monthly charges for access and transmission. However, the price paid will depend on a number of factors, including location of head office, and number and type of branches (ie, whether they are connected to metro or other exchanges). In consultation with the Commission, two services were used to determine the price of the representative product: Frame Relay and DDS. The prices of these services, which were provided to the Commission by TCNZ, are based on a sample customer. A summary of these sample prices is presented in Table 5.7.

Table 5.7: TCNZ's data services (sample customer) (NZ$)

Data product	Installation charge	Access charge (monthly)	Transmission charge (monthly)
Frame Relay[1]	[✂] TDR	[✂] TDR	[✂] TDR
DDS[2]	[✂] TDR	[✂] TDR	[✂] TDR

Note: [1] This refers to a sample customer with **[✂] TDR**. [2] This refers to a sample customer with **[✂] TDR**.
Source: Data received from TCNZ, July 16th 2003; updated December 1st 2003.

The variable price of the representative products is an average of the annualised access and transmission charges, weighted by the proportion of customers taking these services.[40] The resulting price corresponds to an average price for a sample customer with [✂] TDR. This average price has been expressed in terms of average price per tail/exchange. The resulting annual price per tail corresponds to P_0, and is NZ$[✂] TDR.

[40] Data received from TCNZ, July 16th 2003.

Downward cost pressure is also expected in Option 4, but the expected price reduction is lower, at 3%. P_0 is expected to fall to NZ$**[✂] TDR** by the end of the CBA.

5.3 Price derivation and price levels under specification

5.3.1 Methodology

As noted in the introduction, specification implies that prices are subject to competitive pressures. The effects of competition are modelled by calculating the specified prices using a top-down approach. Two prices are calculated: P_1 and P_2. P_2 is the retail price that would emerge as a result of full competition. Full competition is defined as the case where there are at least two entrants in addition to TCNZ in a specific ESA. Prices follow a glide path to reach P_2 over the five-year period used. It is assumed that the retail prices of TCNZ and those of the entrants will converge at this price—ie, at this point, P_2 is the same for TCNZ as for the other two entrants.

P_1 is the price an entrant would be able to charge if there were only one entrant. It is assumed that the full benefits of competition will not be obtained in this instance; therefore P_1 is slightly above P_2. TCNZ is assumed to match this entry price. This approach contrasts with the approach taken previously, where it was assumed that TCNZ would not drop its price as far as the entrant's price.

P_2 is calculated according to the following formula:

$$P_2 = P_0 - \%\,\Pi - \text{efficiency} + \text{unbundling costs}$$

- **P_0** is TCNZ's pre-entry retail price, as discussed in section 5.2.

- **% Π** is the reduction in TCNZ's profitability that would be expected given full competition. A reduction of 5% of the pre-entry price P_0 is assumed in the central case. Previously, in the draft paper, this had been set at 10%. Following the Conference, it was felt that 5% was a more appropriate profitability target. This gain occurs in the first year of specification.

- ***Efficiency*** is the underlying assumption that TCNZ will become more productively efficient when competition is introduced. An annual efficiency gain of 2.5% is assumed in the central case. Over the five-year period, this would imply a 13% reduction in P_0 after the introduction of specification.

  The efficiency parameter incorporated in the CBA is based on OXERA's analysis of TCNZ's efficiency, as detailed in the accompanying paper, 'Estimating the Relative Efficiency of Telecom New Zealand'.

  OXERA was initially presented with analysis carried out by PricewaterhouseCoopers Consulting, which showed that TCNZ was as efficient as the best US local telecoms operators.[41] Subsequent analysis identified some flaws in the procedures adopted in the estimation of TCNZ's efficiency; in addition, OXERA was provided with more information by TCNZ. Correcting for the methodological flaws and including the additional information enabled OXERA to calculate a range of estimates for the efficiency improvements that TCNZ would have to make in order to become efficient. The range calculated when considering operating costs is 3.4–7.4%. The analysis includes sensitivities using 'total costs' (rather than operating costs only). This yielded a range of 0.7–4.7%. In the modelling, 2.5% was employed to reflect the mid-point of the 'total cost' estimated range and the lower end of the more robust operating cost- reduction range. See the accompanying OXERA paper for further details.

Furthermore, the efficiency improvements deducted from the price allow only for catch-up to the efficiency frontier, and do not adjust for the shifting of the frontier over time. In high-technology industries, the frontier is considered to move relatively quickly due to technological improvements. Therefore, even if TCNZ were on the frontier, annual efficiency gains could still be expected. In summary, the efficiency allowance in the model is a conservative estimate.

The efficiency estimate has been reduced since the Conference, from 3% to 2.5% per annum. This is in light of the additional modelling work undertaken and the additional information supplied by TCNZ.

- **Unbundling costs** are costs incurred which would not be incurred in the counterfactual. These must be recovered. The main costs relate to the set-up of TCNZ's OSS and the costs of regulation (submission and Commission costs) incurred by the entrant. The costs of regulation under specification are calculated at half of the level of costs incurred under designation.[42] Therefore, regulatory costs of NZ**[$✂] CDR** are allowed per connection in each option under specification. OSS costs per connection depend on the level of costs incorporated (see below). The range, however, is NZ**[$✂] CDR** per line, under specification.

The level of regulatory costs was set by the Commission, which also attached a degree of probability (80%) to the likelihood of there being an inquiry. Accordingly, total entrant regulatory costs (under designation) are set at NZ$**[$✂] CDR**—NZ$**[$✂] CDR** of Commission costs[43] and NZ$**[$✂] CDR** of submission costs. This is recovered through prices by spreading across 50,000 DSL lines and amortising over a five-year life. The '50,000 lines' figure is used as a conservative estimate of DSL lines that an entrant may acquire over the life of the CBA. This level of regulatory costs to be recovered is similar to the level used in the draft report.

[41] PwC Consulting (2002), 'TCNZ Efficiency Study Based on Stochastic Frontier Analysis (SFA)', September
[42] Commission decision. See NZCC (2003), 'Part 3C: Estimates of Regulatory Costs', November 27th (revised).
[43] The Commission has ruled that its costs should be recovered 50% from TCNZ and 50% from the entrant(s). NZCC (2003), 'Part 3C: Estimates of Regulatory Costs', November 27th (revised).

The Commission allowed that TCNZ should recover all reasonable costs associated with implementing OSS that result from unbundling. These costs should be recovered over all DSL lines—a figure of 250,000 lines is used to represent an average number of DSL lines over the life of the CBA.

At the Conference there was considerable discussion about the appropriate level at which such costs should be set. In conjunction with the Commission, it was decided to allow for three levels of OSS cost: low, central and high. The low case assumes that additional OSS costs are zero, on the basis of the wholesale experience in New Zealand where there is no charge for OSS. This does not mean that customers make no contribution, since the wholesale access charges include some element for recovery of OSS. It was not possible to ascertain whether this was the case, but, at least in Australia and the UK, it appears to be that the wholesale access charges provide a mechanism for recovery of OSS charges. For example, Oftel states:

> BT should be able to recover its reasonable system set-up costs. Oftel is content that these be recovered from the connection charge on individual loops.[44]

The central case allows for **NZ$[✂] TDR** in onset and ongoing OSS costs over the life of the CBA; the high case allows for **NZ$[✂] TDR**. These costs are allocated over 250,000 DSL lines, where this number represents an average of the DSL lines in the counterfactual. Since there are likely to be more DSL lines in the options, this approach is conservative.

For all three cost levels, it is assumed that the OSS system would initially be operated manually, and that this would continue until a sufficient volume of local loops is being unbundled to justify automating the process.

This approach contrasts to the **NZ$[✂] TDR** of OSS costs that were allowed to be recovered from consumers in the draft report.

For Option 4, where prices under designation are also calculated on a top-down basis for the unbundling of the fixed PDN, 100% of these costs are added back.

As discussed elsewhere in section 4, following on from the Conference it was decided that prices in the options should fall by a further percentage (5% in Options 1–3; 3% in Option 4) over the CBA to reflect downward cost pressure.

P_1 is calculated as:

$$P_1 = P_2 * (1 + \text{uplift factor})$$

[44] Oftel (2000), ‘Access to Bandwidth: Conclusions on Charging Principles and Further Indicative Charges’, August.

The uplift factor is set at 10%, and is applied to the P_2 achieved in year 5, before ISP charges, GST and the price drop due to cost pressure. These are then added back.

As noted, given entry by one operator, it is assumed that TCNZ responds by matching that entry price.

5.3.2 Price levels in the options under specification

This section summarises the price levels used in the options, as derived using the foregoing methodology. Counterfactual prices are also shown.

Table 5.8 shows:

- the annual P_2 for the representative bundled voice and data product which results after a five-year period, both for residential and business customers. This includes the price drop due to cost pressures. ISP charges are also included, at NZ$214 per annum for business customers, and NZ$180 per annum for residential customers;
- the annual P_1, where this is the price charged by the entrant when it is the only new operator. It is assumed that TCNZ responds by matching that entry price;
- the counterfactual prices.

Table 5.8: Retail prices under specification (NZ$ per year)—full unbundling

Price	Residential customers	Business customers
	Voice and data	Voice and data
P_0 (starting)	1,255	2,414
P_0 (year 5)	1,044	2,304
P_2 (year 5)	917	2,028
P_1 (year 5)	996	2,209

Notes: One-off connection charges are not shown but are assumed to remain constant, as in the counterfactual.
Source: OXERA calculations.

Table 5.9 shows the expected prices under specification for Options 2 and 3. It is assumed that the retail prices in the provision of bitstream services for residential and business customers are the same as those estimated under the line-sharing scenario, where the entrant provides data-only services. This is because, although the modes of delivery differ, end products provided to the consumer will be reasonably substitutable, at least initially.

Table 5.9: Retail prices under specification—line sharing and bitstream (NZ$ per year)

Price	Residential customers	Business customers
P_0—starting	783	1,428
P_0—year 5	596	1,368
P_2—year 5	542	1,245
P_1—year 5	584	1,348

Source: OXERA calculations.

For Option 4 (unbundling of the fixed PDN) the estimation of prices under specification follows the same top-down methodology used in the other options. Costs relating to the recovery of TCNZ's OSS costs of NZ$ **[✂] CDR** and regulatory costs of NZ$**[✂] CDR** per year are added to the prices.

However, in contrast to the derivation of designated prices in the other three unbundling options, designated prices in Option 4 are also derived using a top-down methodology. The starting point is the P_2 derived in specification, which is adjusted to include NZ$**[✂] CDR** of regulatory costs (ie, twice the level of specification) and NZ$**[✂] CDR** of OSS costs. P_2 under designation is then 75% of this. Table 5.10 presents the derived retail prices for Option 4 services under specification and designation.

Table 5.10: Retail prices—fixed PDN for specification and designation (NZ$ per year, per tail)

Price	Specification	Designation
P_0—starting	[✂] CDR	[✂] CDR
P_0—year 5	[✂] CDR	[✂] CDR
P_2—year 5	[✂] CDR	[✂] CDR
P_1—year 5	[✂] CDR	[✂] CDR

Source: OXERA calculations.

5.4 Price derivation and price levels under designation

Designation implies that the Commission may be called upon to regulate prices. In this case, it would be regulating the wholesale access prices, which form just one part of the final retail price charged. For Options 1–3, the retail prices charged to end-consumers under designation are determined using a bottom-up or 'cost-stack' approach, comprising:

- the wholesale access prices—one-off connection and ongoing access charges;
- costs incurred as a result of unbundling—backhaul (onset and ongoing), tie cables, collocation (onset and ongoing), switch and infrastructure connectivity, DSLAMs, TCNZ's costs of OSS, and regulatory costs;
- other costs—local calling costs for business, core network OPEX, marketing and ISP costs.

This methodology is used to calculate P_2 under designation. P_1 is calculated using an uplift factor of 10%, as under specification.

Costs and designated prices are closely related in the model, given this approach. This section therefore sets out both the costs that an entrant would expect to face at the level of the ESA, and the prices that a consumer might expect to pay. The aim is to include in prices an annualised, per-connection allocation of all the costs incurred in providing the service relevant to each option;[45] and to include, on the cost side, at an appropriate level, all the onset and annual costs (investment and otherwise) that an entrant could expect to have to meet.

These costs are the basis for the cost side of the NPV calculation used to model the entry decision that an operator might make. They may be grouped as follows, and reflect the constituents of the bottom-up price under designation:

- one-off set-up costs;
- investment in DSLAMs;
- ongoing (per year, per exchange);
- fixed one-off costs per line;
- variable costs per line.

To determine the retail prices in Option 4, as noted in section 5.2.2, prices are calculated on a top-down basis in designation as well as specification. The cost-stack approach is therefore not relevant to Option 4, but the costs at the level of the ESA are important, as they form part of the operator's decision about whether to enter.

5.4.1 Wholesale access charges

Wholesale access charges form part of the costs used to determine the designated prices under Options 1–3. The access charge is included in the price as a cost amortised over five years—the expected life of a connection. This approach is not relevant to Option 4, where the designated prices are top-down.

The appropriate wholesale access prices for the modelling have, in part, been provided to the Commission by Covec Ltd.[46] Covec's report included average and median access (ie, ongoing) and connection charges for full and shared access, under designation. For the purposes of the modelling, the median numbers were used for Options 1 and 2—these costs are shown in Table 5.11.

Covec also discussed a methodology for deriving wholesale rental charges and access connection charges for Option 3 (bitstream), based on a modified retail-minus approach. OXERA decided not to use a retail-minus approach since, within the context of potential unbundling, the retail price may not be stable.

Instead, for Option 3, the wholesale cost was decomposed into the onset and ongoing cost of access to the copper, plus the onset and ongoing (ie, collocation) cost of access to the DSLAMs that form part of the bitstream service. An allowance for the cost of capital (at

[45] This approach does not provide a LRIC-type result. The methodologies appear similar, but the cost-stack approach to pricing under designation cannot be as precise as a LRIC-type approach due to time constraints. Moreover, there is no explicit assumption about the level of cost recovery.
[46] Covec (2003), 'Pricing of Unbundled Access for New Zealand Commerce Commission', December.

18%) was built into this cost. These latter costs amounted to NZ$74.4 per annum, and are included in the monthly access fee shown in Table 5.11.

Table 5.11: Wholesale access (ongoing) and connection charges under designation for Options 1–3

Option	Monthly access fee (NZ$)	Connection charge (NZ$)
Option 1—full access[1]	23.79	116.8
Option 2—line sharing[1]	10.03	174.83
Option 3—bitstream[2]	16.23	174.83

Source: [1] Covec (2003), 'Pricing of Unbundled Access for New Zealand Commerce Commission', December; [2] OXERA calculations.

It is assumed that these costs are the same for business and residential connections.

On the cost side, the levels of charge discussed above are included for Options 1–3 under designation, with the onset access charge incurred as a per-line cost in the first year of unbundling and the annual charge included in the variable costs per line. These cost levels under designation are 75% of the level included on the cost side under specification.

For Option 4, both the per-tail access and ongoing charges included on the cost side are calculated on a top-down basis, with the level under designation set at 75% of that under specification:

- the wholesale connection charge is assumed to be equal to the one-off retail installation charge (NZ$**[✂] TDR**)[47] minus 16%,[48] and re-expressed in terms of cost per tail per exchange;
- the ongoing wholesale line rental charge is set at the retail price level minus 16%.[49] Two such charges are calculated—one relating to P_1 and one to P_2.

These per-tail costs are shown in Table 5.12.

Table 5.12: Wholesale access (ongoing) and connection charges under designation for Option 4, included in costs

Option	Monthly access fee (NZ$)	Connection charge (NZ$)
Option 4—fixed PDN	[✂] TDR (relative to P_2)	537.6
	[✂] TDR (relative to P_1)	537.6

Source: OXERA calculations.

[47] Data received from TCNZ, July 16th 2003.
[48] This level was chosen in order to be consistent with the wholesale determination.
[49] This level was chosen in order to be consistent with the wholesale determination.

5.4.2 Costs of unbundling

Costs incurred as a result of unbundling are:

- backhaul (onset and ongoing);
- tie cables;
- collocation (onset and ongoing);
- switch and infrastructure connectivity;
- DSLAMs;
- TCNZ's costs of OSS;
- regulatory costs.

Each of these must be included in the costs stack that makes up each P_2. Each must also be included on the cost side as a cost that the entrant will face on entry.

In the case of Option 1, the costs have been estimated assuming that the entrant will take advantage of unbundling in order to provide both voice and data services. Although voice-only customers are supplied solely where the exchange is also unbundled for voice and data services, for modelling purposes data is treated as the incremental service. Each cost element is explained below.

Backhaul (onset and ongoing)

Onset backhaul costs have been calculated using information supplied by TelstraClear (Table 5.13).[50] The TelstraClear information is based on experience of the cost of laying fibre from TelstraClear's network to TCNZ's exchange. These cost figures apply in the provision of data and voice services.

Table 5.13: Backhaul set-up costs—Option 1, voice and data (NZ$)

Type of ESA	NZ$
Metro	10,000
Urban	140,000
Suburban	285,000
Rural	510,000

Source: OXERA calculations, based on information supplied by TelstraClear.

Onset backhaul costs for Option 2 (line sharing) are assumed to be 95% of this level, since there are no voice costs to include. Onset backhaul costs for bitstream (Option 3) are assumed to be 50% of the line-sharing level, since the entrant is buying a service that will include backhaul to the first point of interconnection. The costs for Option 4 are set at 40% over the level for Option 3. These cost levels are shown in Table 5.14.

[50] Response received from TelstraClear, 'TelstraClear Build Costs to Telecom ESAs', November 17th 2003.

Table 5.14: Onset backhaul costs (specification and designation) for Options 1–4 (NZ$)

Type of ESA	Option 2	Option 3	Option 4
Metro	9,500	4,750	6,650
Suburban	270,750	135,375	189,525
Urban	133,000	66,500	93,100
Rural	484,500	242,250	339,150

Source: OXERA calculations.

An annual cost per connection for inclusion in the bottom-up price is derived by calculating a weighted average cost per ESA based on the average number of potential broadband lines by type of ESA. The weights are: metro (**[✂] TDR** %), urban (**[✂] TDR** %), suburban (**[✂] TDR** %), and rural (**[✂] TDR** %).

This is then converted to a per-connection cost based on 1,000 connections per exchange, amortised over an expected economic life of 20 years. The expected economic life is based both on experience from other jurisdictions (as considered by consultants, ICC), and on evidence submitted at the Conference.

For residential customers, this results in NZ$9.6 per connection per year for Option 1; NZ$9.1 per connection per year for Option 2; and NZ$4.5 per connection per year for Option 3. The costs are assumed to be 30% higher for business connections.

Ongoing backhaul costs are included on the cost side for Options 1–4, calculated as 1% of onset backhaul costs. This is converted into a per-connection cost for the bottom-up prices of Options 1–3 using the same methodology as outlined above.

Tie cables

Tie cables costs are set at between NZ$500 and NZ$2,000 per exchange.

For Options 1 and 2, a per-line cost for the bottom-up price is derived by calculating a weighted average cost per exchange, calibrated using 1,000 lines per exchange and amortising over 15 years. This amounts to less than NZ$1 per subscriber per year. The per-connection cost for Option 3 is 50% of this level.

Collocation (onset and ongoing)

Collocation costs refer to the costs of establishing, on an ongoing basis, telehousing space in an existing exchange, and as such is only relevant to Options 1, 2 and 4. The level of costs included in Option 4 is set at 50% of the level included for the other two options, as the Commission advised that less space is likely to be needed.

Cost information has been supplied by TCNZ.[51] The costs include provision of seismic frames and cable trays, fire protection, air conditioning, power, project management and contingency allowance, and have been calculated for a two-bay co-mingling area consisting of three rack shelves.

Based on 1,000 lines, the total set-up cost is NZ$[✂] TDR, or NZ$[✂] TDR per line per year, assuming a ten-year life. This is the level of onset cost that has been included in the bottom-up prices for Options 1 and 2.

The total cost per line is aggregated up to give a total set-up cost at the level of the ESA by multiplying through by the average number of broadband lines an entrant is assumed to achieve, by type of ESA. Table 5.15 shows the level of costs under designation for Options 1, 2 and 4.

Table 5.15: Collocation set-up costs under designation, Options 1, 2 and 4 (NZ$)

Type of ESA	Options 1 and 2 (NZ$)	Option 4 (NZ$)
Metro	[✂] TDR	[✂] TDR
Urban	[✂] TDR	[✂] TDR
Suburban	[✂] TDR	[✂] TDR
Rural	[✂] TDR	[✂] TDR

Source: OXERA calculations, based on information supplied by TCNZ

The costs in Table 5.15 are based on a linear relationship between collocation costs and lines as the number of lines increases (or decreases). There may be economies of scale which would suggest that the per-line cost would fall as the number of lines increases, and diseconomies of scale that increase the per-line cost for fewer than 1,000 lines. However, the modelled approach could be considered conservative, as it overstates the costs in exchanges that are most likely to be subject to entry (metro, urban and possibly suburban), and understates them in exchanges where entry is least likely to occur (rural).

It was therefore considered that the assumption of linearity in the collocation costs was unlikely to overstate the welfare benefits, and so the approach laid out above was adopted.

It has been assumed that the estimation supplied by TCNZ would apply in the designation scenario and that costs under specification would be higher. To reflect this, designated costs are set at 75% of specified costs.

Ongoing collocation costs are also included, to account for the rental of space and running costs such as electricity. Based on information supplied by TelstraClear,[52] space

[51] Data received from TCNZ, and supplied to OXERA by the Commission on November 28th 2003.
[52] Data received from TelstraClear, and supplied to OXERA by the Commission on November 28th 2003.

rental for two bays would amount to NZ$[✂] TelstraClearDR per year, and annual power costs would be NZ$[✂] TelstraClearDR. These costs are based on 1,000 lines; hence, a per-line cost is derived by dividing by 1,000, to give NZ$[✂] TelstraClearDR, included in the bottom-up prices for Options 1 and 2.

As for total collocation set-up costs, the total per-line cost is aggregated up to give a total set-up cost at the level of the ESA by multiplying through by the average number of broadband lines an entrant is assumed to achieve, by type of ESA. Table 5.16 shows the level of costs, which are assumed equal under designation and specification.

Table 5.16: Annual collocation costs for both designation and specification (NZ$)

Type of ESA	Options 1 and 2 (NZ$)	Option 4 (NZ$)
Metro	[✂] TelstraClearDR	[✂] TelstraClearDR
Urban	[✂] TelstraClearDR	[✂] TelstraClearDR
Suburban	[✂] TelstraClearDR	[✂] TelstraClearDR
Rural	[✂] TelstraClearDR	[✂] TelstraClearDR

Source: OXERA calculations, based on information supplied by TCNZ.

Switch and infrastructure connectivity

These costs are relevant to Options 1–3, for both data services and for voice services. There are assumed to be no common costs between them.

For Option 1 only, the provision of voice services would require the entrant to install switches and infrastructure connectivity. Based on experience in other jurisdictions, as considered by ICC, this cost has been estimated at NZ$2m per 2,000 connections. The figure has been converted into a per-connection cost on the basis of an amortisation over an expected economic life of ten years. This gives a figure of NZ$100 for inclusion in the bottom-up price for Option 1 for residential consumers. The figure is assumed to be 30% higher for business customers.[53]

The total set-up cost at the level of the ESA is obtained by multiplying through by the average number of voice lines an entrant is assumed to achieve, by type of ESA. Table 5.17 shows the level of cost this implies. It also shows the switch and infrastructure costs incurred on the data side for Options 1–3. Data services require the installation of data traffic aggregation equipment at the entrant's point of interconnection. The provision of Internet-grade services has been estimated to cost NZ$154,000 for up to ten ESAs.[54] The

[53] It is acknowledged that there may be economies of scale and therefore the relationship between costs of the switch and number of lines may not be linear.
[54] Estimate provided by the Commission.

per-ESA cost is therefore calculated at NZ$15,400, and the per-line cost is derived by amortising over ten years and calibrating at 1,000 connections. This gives NZ$1.54, which is included in the bottom-up prices for Options 1–3.

Table 5.17: Switch and infrastructure connectivity costs—specification and designation (NZ$)

Type of ESA	Option 1—voice costs	Options 1–3—data costs
Metro	6,021,280	15,400
Urban	528,797	15,400
Suburban	2,051,926	15,400
Rural	56,445	15,400

Source: OXERA calculations.

DSLAMs

DSLAM costs are relevant to Options 1–3, although the costs included at the level of the ESA and in the bottom-up prices for Option 3 have a slightly different basis. DSLAM costs are included in Option 3 as part of the ongoing wholesale charge and have been discussed already (see section 5.4.1).

For Options 1 and 2, investment in DSLAMs is required on the part of the potential entrant. The fixed costs of installing DSLAMs for data services depend on the number of connections per exchange, as supplied by TCNZ. TCNZ also provided DSLAM node capital costs, depending on the number of connections.[55] These costs have been revised downwards since the draft report, to reflect a reasonable estimation of DSLAM costs based on market information and data supplied to the Commission by interested parties. Table 5.18 shows the level of cost included in the model, depending on the number of connections.

Table 5.18: DSLAM costs in Options 1 and 2—specification and designation

Number of connections	Cost (NZ$)
80	[✂] CDR
160	[✂] CDR
500	[✂] CDR
1,000	[✂] CDR
2,000	[✂] CDR
3,000	[✂] CDR

The model chooses the size of DSLAM that is required to serve the expected number of subscribers over a two-year investment cycle—ie, every two years after the initial

[55] Data received from TCNZ, August 8th 2003.

upgrade of the ESA, it checks whether a new DSLAM is necessary to cope with the expected demand for the subsequent two years. In this way, an investment is only made as the need arises. There is no difference between specification and designation.

These costs are converted into a per-connection cost by assuming an average of 1,000 connections. The resulting cost is NZ$[✂] CDR per connection, which is amortised over an expected economic life of five years (based upon submissions made at the Conference). This is down from NZ$[✂] TDR in the draft report.

It is assumed that these costs are the same for residential and business connections, and, furthermore, that the capital costs of the DSLAMs remain the same in the provision of data-only services, and combined data and voice services.

For Option 4, NZ$500 has been included in the fixed costs per line to account for the cost of multiplexing equipment.

TCNZ's OSS costs

The level of OSS costs to be recovered is discussed above under specification in section 5.3. As mentioned in specification, the level of OSS costs included depends on whether the scenario is 'low', 'central' or 'high'.

Costs of NZ$[✂] CDR per connection are included in the bottom-up price under designation, and are included as part of the variable per-line charge on the cost side.

Regulatory costs

The issues related to costs of regulation are also set out in section 5.3, as these form part of the costs that must be added back under specification, although only 50% is added back under specification; 100% is included under designation. These costs are included on the cost side as part of the variable per-line charge.

Costs of NZ$[✂] CDR per connection are included in the bottom-up price under designation, and are included as part of the variable per-line charge on the cost side.

5.4.3 Other costs

Other costs include core network OPEX, marketing, ISP and local calling costs.

Core network OPEX

The estimation of the core network operating costs has been based on BT's regulatory accounts for the year 2002, because no disaggregated information between network and non-network elements for TCNZ and TelstraClear was available.

The approach adopted is as follows: the proportion of network OPEX over total OPEX of BT's wireline business (ie, Network, Retail Narrowband Access business, and Retail

Systems business) is estimated.[56] The total OPEX for the wireline business excludes notional payments from BT Network. This results in a proportion of 11.6%, which is applied to TCNZ's total OPEX (NZ$1,214m) for the wireline business, as contained in TCNZ's Annual Report for the year ended June 30th 2002. This gives an estimated NZ$141.1m for an entrant's core network OPEX.

For Option 1, the headline per-connection cost used is NZ$83, derived by dividing the total figure by the number of TCNZ access lines at the end of June 2002, estimated at 1.7m. The cost per business connection is set at NZ$91, since more network capacity may be required for business connections.

The per-connection charge for Options 2 and 3 is set at NZ$70 for residential customers, to reflect the fact that no voice services are included. The business cost is NZ$91.

These costs are aggregated up to the level of the ESA by multiplying by the average number of broadband lines that an entrant might expect to unbundle over the CBA, by type of ESA. The costs for Option 4 are set at the same level as for Options 2 and 3. These costs are show in Table 5.19.

Table 5.19: Annual core network OPEX costs—designation and specification

Type of ESA	Option 1 (NZ$)	Options 2–4 (NZ$)
Metro	441,939	372,734
Urban	38,812	32,734
Suburban	150,603	127,020
Rural	4,143	3,494

Source: OXERA calculations.

Marketing costs

Marketing and customer-service costs for voice and data services combined (ie, Option 1) have been estimated at NZ$60 per residential connection. It is assumed that there would also be some marketing activity undertaken by the ISP, hence this allocation does not account for the entire marketing spend per connection. These costs are reduced to NZ$40 for residential connections under Options 2 and 3.

In all cases, marketing costs for business connections are assumed to cost 30% more than residential connections.

The same level of cost is included on the cost side in the variable per-connection cost.

For Option 4, NZ$52 is included in the variable per-connection costs.

[56] The categories included in the network OPEX are main and digital junction switch; local to remote transmission (link and length); local to tandem transmission; tandem to tandem transmission; product management; interconnect connections; and data services.

ISP services

It has been assumed that the provision of ISP services is already competitive. Thus, the retail price of these services includes only a return on investment. Accordingly, the costs of providing the services are set at the same level as the retail price—ie, for residential services, the entrant incurs NZ$120 of annual cost; and, for business, NZ$214. This is a conservative assumption, as it does not allow any contribution from ISP services to support the entry decision.

This level of cost is included in the bottom-up price and as part of the variable per-line connection cost on the cost side.

Local calling

Costs and revenues associated with local calling are only relevant to the provision of voice services to business customers in Option 1. As local call charges are excluded from the voice access price for business customers, a representative revenue allocation (as described in section 5.2.1) has been included in the calculation of the bottom-up price for designation. The revenue included in this price is based on a top-down calculation in the same way as prices are derived under specification, with an assumed 15% reduction in profitability. This gives a level of NZ$202.

On the cost side, the costs are included in core network OPEX.

5.4.4 Summary—final prices under designation

Table 5.20 presents the resulting prices for the bundled voice and data product under designation. As in the specification scenario, P_1 under designation is assumed to be 10% higher than P_2. For purposes of comparison, the table also presents the value of P_0, which would prevail if no entry occurs under designation, and P_1, the one-firm entry price.

Table 5.20: Retail prices under designation (NZ$ per year)—Option 1

Price	Residential customers Voice and data	Business customers Voice and data
P_0—starting	1,255	2,414
P_0—year 5	1,044	2,304
P_2 —year 5	829	1,105
P_1—year 5	900	1,194

Source: OXERA calculations.

Table 5.21 presents the resulting prices for line sharing under designation, together with P_0 and P_1.

Table 5.21: Retail prices under designation—Option 2 (NZ$ per year)

Price	Residential customers	Business customers
P_0—starting	783	1,428
P_0—year 5	596	1,368
P_2 —year 5	523	607
P_1—year 5	564	646

Source: OXERA calculations.

Table 5.22 presents the resulting prices for Option 3 under designation.

Table 5.22: Retail prices under designation—Option 3 (NZ$ per year)

Price	Residential customers	Business customers
P_0—starting	783	1,428
P_0—year 5	596	1,368
P_2—year 5	512	602
P_1—year 5	551	640

Source: OXERA calculations.

A summary of prices for the unbundling of Option 4 (fixed PDN) is provided in Table 5.10.

5.4.5 Summary—costs in each option

Table 5.23 provides a summary of all the costs that enter the NPV decision on the cost side.

Table 5.23: Summary of costs that enter the NPV decision for each option (NZ$) [Whole Table CDR]

	Option 1: Full LLU		Option 2: Line sharing		Option 3: Bitstream		Option 4: Fixed PDN	
	Specification	Designation	Specification	Designation	Specification	Designation	Specification	Designation
Data set-up costs—collocation costs, backhaul, tie cables, switch and infrastructure connectivity costs								
Metro	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Suburban	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Urban	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Rural	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Voice set–up costs—backhaul, and switch and infrastructure connectivity costs								
Metro	[✂]	[✂]						
Suburban	[✂]	[✂]						
Urban	[✂]	[✂]						
Rural	[✂]	[✂]						
Ongoing costs—core network OPEX, ongoing collocation and backhaul								
Metro	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Suburban	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Urban	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Rural	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Fixed costs per line—wholesale connection charge plus multiplexing transmission equipment (Option 4 only)								
Data business	–	–	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Data residential	–	–	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Voice and data business	[✂]	[✂]	–	–	–	–	–	–
Voice and data residential	[✂]	[✂]	–	–	–	–	–	–

	Option 1: Full LLU		Option 2: Line sharing		Option 3: Bitstream		Option 4: Fixed PDN	
	Specification	**Designation**	**Specification**	**Designation**	**Specification**	**Designation**	**Specification**	**Designation**
Variable costs per line, pa— wholesale ongoing access charge, marketing, ISP costs, OSS costs, regulatory costs, DSLAM costs (Option 3 only)								
Data business (PDN only)							[✂][1] [✂][2]	[✂][1] [✂][2]
Data business	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Data residential	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Voice business	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Voice residential	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Notes: [1] Calculated on a retail-minus basis, relative to P_1; [2] Calculated on a retail-minus basis, relative to P_2.

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NEW ZEALAND COMMERCE COMMISSION

ESTIMATING THE RELATIVE EFFICIENCY OF TELECOM NEW ZEALAND

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Executive Summary

This study examines the relative efficiency of Telecom New Zealand (TCNZ), using comparisons with the US local exchange carriers. The analysis in this paper has been carried out in order to provide an input into OXERA's cost–benefit modelling of unbundling TCNZ's local loop network and fixed public data network.

Prior to undertaking the modelling, numerous adjustments were made to the data in order to improve comparability between TCNZ and the US local exchange carriers. However, given the level of adjustments and assumptions required, significant sensitivity testing was also carried out.

The results of this study are derived from employing three higher-level model specifications:

- a comparative-efficiency assessment of operating expenditure (OPEX) only, using stochastic frontier analysis (SFA) and data envelopment analysis (DEA);
- a comparative-efficiency assessment with OPEX and capital expenditure (CAPEX) as two separate inputs, using DEA;
- a comparative-efficiency assessment with 'total cost' measure as the sole input, using SFA and DEA.

A summary of the main results is provided below.

Summary results of all models

Model	Target cost reduction (% pa)	
	Range	Point estimate (based on geometric mean of all models)
SFA model		
operating costs including marketing	3.4–6.5	4.7
operating costs excluding marketing	5.0–7.4	6.6
DEA model		
operating costs including marketing	5.4–7.5	6.2
operating costs excluding marketing	7.9–10.2	8.8
SFA model		
total costs including marketing	1.1–3.3	2.1
total costs excluding marketing	1.9–4.7	3.0
DEA model		
total costs including marketing	0.3–3.0	1.0
total costs excluding marketing	1.6–4.2	2.5
DEA two-input model		
operating costs including marketing, and capital costs	0.7–3.2	2.0
operating costs excluding marketing, and capital costs	1.4–3.9	2.2

However, given the difficulties of quantifying CAPEX, OXERA considers that the OPEX specifications are more satisfactory, although the resultant inefficiency range from these models is tempered by the fact that TCNZ performs better on the ‘total cost’ model specifications. Thus, OXERA considers that a robust estimate for the potential cost reductions for TCNZ ranges between 2.5% and 5% per annum over a five-year period—ie, between the upper end of the resultant ranges from the total cost models and the lower end of the resultant ranges from operating cost models.

This range represents the required savings TCNZ needs to achieve in order to reach efficient performance corresponding to the year 2000 (the year to which the data used in the analysis corresponds). In other words, the above estimate relates to a measure of catch-up or static efficiency. The estimation of the scope for future frontier shift—ie, the potential of the industry to achieve productivity gains over time due to technical and technological advances—was beyond the remit of this study.

This is a public version of the report, from which confidential commercially sensitive information has been removed. Where this has occurred, the relevant text or data has been replaced by square brackets [✂].

Contents

1. Introduction

This study examines the relative efficiency of Telecom New Zealand (TCNZ) using comparisons with the US local exchange carriers (LECs). The analysis in this paper has been carried out in support of OXERA's cost–benefit modelling of unbundling TCNZ's local loop and fixed public data network, undertaken for the New Zealand Commerce Commission. This paper should therefore be considered in conjunction with the OXERA paper 'Modelling the Impact of Unbundling the Local Loop and Fixed Public Data Network', and the outputs from the analysis have been used to inform the modelling presented therein.

This paper should be considered as an update of the previous OXERA study commissioned by the New Zealand Commerce Commission dealing with the estimation of TCNZ's relative efficiency.[57]

The remainder of this report is structured as follows:

- section 2 provides a theoretical framework for the implementation of a comparative-efficiency analysis;
- section 3 describes the data used in the analysis;
- section 4 presents the results of the analysis;
- section 5 provides conclusions.

The process adopted in this study for measuring relative efficiency, and thus the outcomes produced, is heavily influenced by the analysis previously submitted by TCNZ. This was mainly due to binding time constraints and the availability (or lack) of detailed cost and operational information for the telecommunications operators used in the analysis (including TCNZ itself). Therefore, where there might be some ambiguity in the data or assumptions used, OXERA has undertaken sensitivity analysis to provide a range of results.

The results of this study represent the required savings TCNZ needs to achieve in order to reach efficient performance corresponding to the year 2000 (the year to which the data used in the analysis corresponds). In other words, they are a measure of static, or cross-industry, efficiency, which is commonly referred in the relevant literature simply as 'efficiency'. (The measure used to describe the distance between a company's current position and the static efficiency frontier is usually referred to as the 'catch-up percentage'.) There is also the concept of dynamic efficiency, or productivity, which relates to improvements in the effectiveness of the inputs-to-outputs transformation process over time, due to technical and technological advances. It is believed that the telecommunications industry can achieve rapid technical and technological progress, and

[57] OXERA (2003), 'Efficiency Analysis to Support Cost–Benefit Analysis', a report for the New Zealand Commerce Commission, October 14th 2003, available at http://www.comcom.govt.nz/telecommunications/llu/Appendices14Oct2003.PDF.

thereby secure large productivity gains. (The measure used to describe the distance from the current frontier to the estimated future frontier is usually referred to as the ‘frontier shift’.) To control for these potential productivity gains, a frontier-shift element needs to be estimated and added to the catch-up percentage; however, this was beyond the remit of this study.

Professor Emmanuel Thanassoulis of Aston Business School, one of the leading academics in the field of comparative-efficiency analysis, has kindly provided a peer review of this study, for which OXERA is grateful.

2. The Comparative-efficiency Framework

Comparative efficiency has seen widespread application in the regulation of utility companies. The comparative-efficiency analysis in this paper provides an important input into OXERA's cost–benefit modelling of unbundling TCNZ's local loop and fixed public data network, undertaken for the New Zealand Commerce Commission.

Given the importance of the results of comparative-efficiency analysis, it is crucial for the exercise to be as robust as possible, subject to the nature of the industry examined and the availability of data on possible comparators. **To ensure that cost-reduction targets are achievable and not unduly onerous, in several instances OXERA has given TCNZ 'the benefit of the doubt' in possible cost-allocation issues, and has adopted a conservative approach. In other words, where there is some ambiguity, the assumptions that benefit TCNZ are used, rather than potentially more stringent assumptions. Moreover, OXERA has undertaken significant sensitivity analysis.**

The general comparative-efficiency framework adopted for this study is summarised below.[58]

2.1 Definition of the measure of efficiency

Efficiency analysis can measure efficiency using either physical inputs (ie, number of hours worked, number of switches used, etc) or costs, although the latter is more suitable for regulatory purposes. The required input into the cost–benefit modelling is an estimate of the potential cost reduction that TCNZ can achieve over the next five years, and hence cost efficiency is the focus of this study. The overall aim of the study is to assess the efficiency of TCNZ in providing the services that enable voice or data services to be exchanged over a fixed-line network.

2.2 The choice of comparators

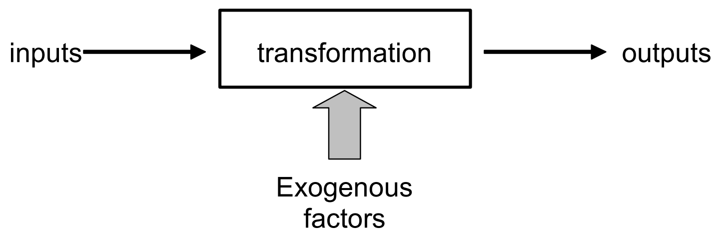
Ideally, comparators should be chosen according to the similarity of their activities and the environment in which they operate (both the regulatory and general business environments). In practice, however, the choice of the comparators is usually based on data availability. OXERA has used the same set of comparators as TCNZ's own commissioned study (ie, US LECs), mainly because of data availability, but also because the LECs undertake similar activities to TCNZ, can be considered as operating in a similar business environment, and are at a stage where local-loop unbundling has already been implemented (as a result of the Telecommunications Act 1996). Where activities differ, the data has been adjusted to ensure comparability (see section 3 and Appendix 1 for a full discussion).

[58] For a more thorough discussion, see OXERA (2003), 'Efficiency Analysis to Support Cost–Benefit Analysis'.

2.3 The choice of relevant inputs, outputs and environmental factors

The choice of the outputs and other factors used in the comparisons is crucial to the results of the analysis. It is also essential that the efficiency assessment provides an appropriate balance between inputs and outputs. Given that the basic function of each unit is to transform a set of *inputs* into a set of *outputs*, the aim of a performance-assessment exercise is to address the issue of the effectiveness with which the unit converts its inputs into outputs, as illustrated in Figure 2.1.

Figure 2.1: Transforming inputs into outputs



The identification of the appropriate inputs and outputs in an assessment of efficiency is crucial. The measures of inputs used in the assessment exercise should capture all resource and environmental factors that have an impact on the outputs. The measures of outputs used should include all outcomes of the assessed unit.

The choice of the input measure(s) is always a critical issue in an assessment exercise. As discussed above, the input measure(s) should ideally encompass all inputs that enter the production process (ie, number of hours worked, plant used, material consumed, etc). An intuitive way to condense all the inputs used in the production process into a single measure is to use a measure of costs incurred. This should ideally cover both operating expenditure (OPEX), which is usually defined as the costs incurred in the day-to-day running of the business, and capital expenditure (CAPEX), defined here as costs relating to the acquisition, replacement or upgrading of assets. However, there are significant problems with developing a total cost measure—in particular:

- there are definitional problems with CAPEX;
- it is not clear what proportion of CAPEX can be substituted with OPEX (and to what degree). Operational trade-offs may exist between the two types of expenditure (eg, it is argued that there is scope for substituting trenched lines, which require large CAPEX but minimum OPEX for maintenance, with aerial lines, which require smaller CAPEX but are more costly to maintain).[59] However,

[59] On the other hand, it is not clear that even such substitution is possible when a network is designed based on optimal network practices. In other words, for a particular part of the network that faces certain topography and customer dispersion, there is no ambiguity as to which is the least-cost solution in the long run. Therefore, a counterargument

the extent of such substitution and the more detailed areas in which it is possible are not easy to assess. To assume that all CAPEX is substitutable with OPEX on a one-to-one basis would be the same as expecting, for example, the acquisition of land worth $100,000 to be able to lower labour costs for maintenance teams by the same amount. Therefore, a total cost measure derived by the sum of OPEX and all CAPEX could be considered theoretically unacceptable.

In addition to the theoretical considerations above, a comparative-efficiency analysis could be hampered by the lack of an appropriate measure of CAPEX or the lack of available data that could be used to construct such a measure. The analysis undertaken in this study had to address this issue as well (for a more detailed discussion, refer to section A1.2). Therefore, in the interests of accuracy and equity, this study focuses on OPEX, although sensitivity analysis is also undertaken using a measure of 'total costs' so that the final efficiency estimate produced would provide a holistic indication of TCNZ's performance.

With regard to the likely outputs and environmental factors to be considered, OXERA has examined previous studies of efficiency in telecommunications in order to identify the potential outputs and environmental factors to be included, and has then undertaken a general-to-specific modelling approach to identify a smaller subset of statistically significant cost drivers.

Furthermore, in principle, the inputs chosen should have the characteristics of *exclusivity and exhaustiveness*, in that only the inputs considered in the analysis influence the output levels, and their influence is restricted to the output factors considered in the analysis. However, this was not possible in the analysis undertaken for this study owing to TCNZ providing an extended set of services compared with the LECs (covering international call and data services, mobile services, and a higher proportion of long-distance call and data services). Therefore, the analysis assumes complete cost separability between activities, although this assumption is unlikely to be true. Further discussion on this issue can be found in Appendix 1.

2.4 Adjustments to data to improve comparability

Adjustments are sometimes necessary to ensure that like-for-like comparisons are made, especially when international comparators are used. Data inconsistencies are usually caused by:

- differences in activities undertaken by the comparator units;
- differences in adopted accounting methods; and
- different definitions of control variables.

could be that, although this operational substitution may be possible, in an environment that does not offer perverse incentives for network design, these decisions are clear-cut.

For operating costs, it is the first issue that requires most careful consideration. In particular, there are many cases in which there are substantial differences between which costs should be included in OPEX, and which in CAPEX, especially when some of the comparators undertake additional functions—as is the case with international calls in this analysis. As a general principle, OXERA has looked at previous studies using LEC data for comparison purposes, examined the cost data categories carefully, together with their definitions (where available), and made the necessary adjustments to ensure comparability as far as possible (for details, refer to section 3 and Appendix 1).

The second issue relates mostly to the definition of CAPEX. For the purposes of a comparative-efficiency assessment, CAPEX should represent the amount of capitalised resources that are consumed within the time period examined in order to produce, or facilitate the production of, a company's outputs. However, since an asset has a useful life beyond a reporting year—which, in this case, is the timeframe of the analysis—a method is needed that robustly quantifies the proportion of the total value of the asset that is 'consumed' in a year. This reduction in value is usually represented by the companies' depreciation expenditure. However, depreciation, as reported in companies' accounts, is an accounting construct, not an economic one, in that a company is allowed significant leeway in predetermining the methodology used for depreciating assets, which is usually determined by that company's need for future CAPEX. Rather, in a cost-assessment exercise, the **economic** notion of depreciation needs to be used, which captures the capital consumption observed in the timeframe of the analysis.

Although a measure of economic depreciation would be the theoretically correct supplementary (to OPEX) cost measure for the assessment exercise, in reality it is very difficult to gather data to construct such a measure. Therefore, the analysis needs to resort to using the accounting definition of depreciation. This, in turn, presents two difficulties.

- CAPEX represents investments in assets that could have very long useful lives—particularly in the case of network industries, where some components (eg, buried cable) can be more than 50 years old. In using the depreciation value of such assets, the analysis implicitly allows the efficiency estimate produced to be influenced by investment decisions taken more than half a century ago.

- The result of allowing a company leeway to set its own depreciation profiles could be that the company's depreciation values have little to do with the assets that are used in the production process. A company that adopts an aggressive depreciation policy could feasibly have most of its older assets written off, but these would continue to contribute to the production process.

To overcome these difficulties, the depreciation measure used needs to be based on the replacement value of the asset base and to be derived by applying a consistent depreciation methodology across the comparator companies. The replacement value of each comparator's asset base would also need to be derived using a consistent methodology. This is the methodology that was attempted for this study. **Unfortunately, the methodology to derive the replacement values of each company's asset base requires such extensive assumptions that the resulting asset base cannot be considered a robust representation of a company's capital inputs. Thus, the focus of the analysis in this study is the assessment of efficient levels of OPEX; nevertheless, although unsatisfactory, the depreciation measure constructed is used to undertake extensive sensitivity analysis**. This sensitivity analysis aids in narrowing the range of the produced OPEX efficiency estimates to derive a measure of 'total cost' efficiency. A more thorough discussion on this subject can be found in Appendix 1.

Where international comparisons are used, some additional standardisation processes are required. Relative differences in input prices, such as wage rates, may create problems in distinguishing between substitution effects and inefficiency. This problem could be resolved by standardising costs to a base currency using a producer purchasing parity (PPP) index. However, the accuracy and overall robustness of PPP measures is sometimes doubtful. Thus, where there are significant differences in input prices, best practice recommends their inclusion as environmental factors in the modelling. Information on price levels was not available for this analysis and thus a combination of the US–New Zealand PPP index and the US–New Zealand exchange rate was used instead. More details are provided in Appendix 1.

2.5 Comparative-efficiency techniques used and validation of the results

This is one of the most important steps, as it will determine the robustness of the final estimates and whether they can be used for regulatory purposes.

Each comparative-efficiency technique has its own requirements and idiosyncrasies. In general, no one technique is superior to any other. As such, the results of this study are based on a number of alternative modelling approaches, including stochastic frontier analysis (SFA) and data envelopment analysis (DEA). For the econometric modelling (ie, SFA), the analysis has used a general-to-specific approach, which is considered best practice in identifying statistically robust models. Furthermore, statistical diagnostic testing, combined with outlier analysis, was undertaken in each stage of the process in order to ensure the robustness of the developed models. Finally, every model was examined to make certain that it predicts intuitively signed and sized relationships between costs and cost drivers.

In summary, the results of this study are derived from employing three higher-level model specifications (although extensive sensitivity analysis has been implemented for each category as well):

- a comparative-efficiency assessment of OPEX only, using SFA and DEA;
- a comparative-efficiency assessment with OPEX and CAPEX as two separate inputs, using DEA;
- a comparative-efficiency assessment of a 'total cost' measure as the sole input, using SFA and DEA.

However, given the difficulties of quantifying CAPEX, OXERA considers that the first specification is the more satisfactory, and thus the final results of this study are more heavily influenced by the results of this approach.

3. Summary of Data Issues

This section summarises the main data issues and data adjustments undertaken by OXERA (further details of which are provided in Appendix 1).

The data relating to the LECs used in this study relates to the 2000 reporting period and was sourced from the Federal Communications Commission's website. The data relating to TCNZ was provided by the company, and was based originally on a comparative-efficiency analysis commissioned by TCNZ. This section summarises the items where major changes have been made to the cost and operational data with respects to TCNZ's earlier comparative-efficiency study. A more complete discussion on the treatment used to arrive at cost and operational data used in the analysis can be found in Appendix 1.

3.1 Cost data adjustments

3.1.1 Cost data adjustments for the LECs

A small number of cost categories have been excluded from the LECs' operating cost base in order to ensure comparability with each other and TCNZ—see below.

6310 Information Origination/Termination Expenses

The cost data supplied by TCNZ excluded a category of costs termed CPE (customer premises equipment), which is the equivalent of the Information Origination/Termination Expenses found in the LEC accounts.

6622 Number Services

This is a sub-category of the Services account that contains costs associated with the provision of customer number and classified listings. The reason for its exclusion was comparability with TCNZ's operating cost base, which excluded costs relating to the provision of directory services, and because the full details of this account for TCNZ were unknown.

6540 Access expenses

This account was excluded from the analysis on the grounds that access costs, which are referred to in New Zealand as interconnect costs, represent rental payments made by the telecommunications operator in question to another operator for access to its network. Given that interconnection charges relate to other operators' costs, and include a profit element, they should be considered as uncontrollable costs and thus removed from the analysis.

6790 Provision for Uncollectible Notes Receivable

This account relates to a provision for 'doubtful debts' (also known as 'bad debts'). This account was excluded from the analysis on the basis that its size depends on regulatory decisions and the accounting systems adopted by the operators (which could also be determined by the regulator).

6610 Marketing

This account is excluded from the operating cost base of the LECs as a form of sensitivity analysis.

3.1.2 Cost data adjustments for TCNZ

As with the treatment applied to the cost base of the LECs, a number of cost items have been excluded for the cost base of TCNZ in order to ensure comparability with the LECs. Given that TCNZ undertakes a wider range of activities than its US counterparts, the costs adjustments implemented for this company are more extensive.

Network OPEX—access/local

Discussions with TCNZ revealed that this cost category included out-payments relating to interconnection charges for local calls and toll bypass calls. According to OXERA's treatment of access costs, and to maintain comparability with the LECs, these items were removed from TCNZ's cost base.

Network OPEX—other data

LECs provide a wide range of data services, including both ISDN and xDSL (ie, high-speed services). Therefore, to maintain comparability, this cost category is also included in TCNZ's cost base in OXERA's analysis.

Network OPEX—other services, mobile, directory etc

The treatment adopted in this analysis is based on the proportion of costs relating to the same category found in the Sales and Services OPEX, for which more disaggregated information was available. Thus, approximately [✂] of the total 'Other services, mobile, directory etc.' account is included in TCNZ's cost base.

Sales and services OPEX—national

The existence of intra-LATA[60] calls implies that the complete exclusion of sales and marketing costs and billing costs relating to TCNZ's national calls, as suggested by the company, is not appropriate. The treatment adopted for this analysis is to include a proportion of the excluded costs equal to the proportion of intra-LATA calls to all long-distance calls handled by the LECs (ie, the sum of intra-LATA and inter-LATA calls). This proportion was estimated US-wide to be 15.25%.

Given that this adjustment may not be very accurate, OXERA also undertook sensitivity analysis in the modelling stage of this study by using two definitions of OPEX. The first includes all sales and marketing costs for the LECs and the above proportion of the relevant costs for TCNZ, while the second excludes such costs from the LECs' cost base and excludes the available values for national sales, marketing and billing expenses from TCNZ's operating cost base.

Sales and services OPEX—other data

As discussed above, LECs provide a wide range of data services. Therefore, in OXERA's analysis, this cost category is included the operating cost base of TCNZ.

[60] LATA is defined as local access and transmission area and denotes the geographical area where a certain LEC is allowed to provide telephony services.

Sales and services OPEX—Other services, mobile, directory etc

Included in this category are a number of items that TCNZ suggested should be excluded. However, it would make intuitive sense that costs for securing interconnect revenue and other revenue as well as error product accounts are also incurred by the LECs; therefore these costs are included in the analysis.

3.2 Capital expenditure

As discussed in section 2, a possible CAPEX measure could be standardised depreciation, based on standardised asset replacement values and a uniform depreciation profile for each asset category. This study made use of the asset valuation methodology that was proposed by TCNZ.

Because the relevant data is not available for the LECs, TCNZ, in its original study, applied its own average asset age to the formula used to convert the LEC asset values. However, this assumption will introduce bias into the analysis. For example, if a LEC has an asset base that is older than TCNZ, the LEC's standardised depreciation measure will be overstated and thus its inefficiency estimate overstated. (The reverse holds for LECs with asset bases that are newer than TCNZ.) Nevertheless, despite the limitations of the constructed standardised 'depreciation' measure, sensitivity analysis is undertaken in this study that incorporates this measure into the cost base.

3.3 Outputs and environmental factors

3.3.1 Access lines

One category of leased access lines (64k-equivalent intra-LATA leased lines) is not reported by the LECs. Although a figure could be estimated based on the revenue received for the provision of leased-line access, the analysis in this study assumes that no LEC provides local private-line services, an assumption that will be beneficial to TCNZ's final efficiency estimate since it reduces the produced output of its comparators.

3.3.2 Number of calls

The number of local calls the LECs report include both answered and unanswered calls, while the equivalent figure available for TCNZ includes only answered calls. Therefore, it is necessary to scale down the LEC figures. Since no estimate of the percentage of answered calls was available for the LECs, the percentage of such calls from TCNZ (76%) was used instead.

3.3.3 Call minutes

The number of call minutes is not available for the LECs and had therefore to be constructed based on estimates of average call duration by type for the whole of the USA. Given that the call-minute measure was constructed, some sensitivity analysis was undertaken to determine the effects of assuming a different set of average call-duration estimates. (The alternative average-call duration estimates were constructed based on the average-call durations used for TCNZ.)

In addition, some calls are operationally more complex than others. The general approach to account for this is to convert call minutes into switch minutes, which take into account the number of switches through which a call passes. The conversion involves multiplying call minutes by a routing factor specific to each call type (supplied directly by TCNZ).

3.3.4 Length of sheath

One factor that tends to affect the costs of all network companies is customer density and dispersion, or customer sparsity. This is often captured in comparative-efficiency studies by using a measure of network length by customer served. In this study the measure used is the length of sheath per access line.

3.3.5 Other environmental factors

The analysis also considers the statistical validity of the length of the local loop and the proportion of business to residential users.

4. Modelling Results

This section summarises the results of OXERA's modelling, providing an overview of the models used, their specification, an indication of their statistical robustness, and the efficiency estimate they produce for TCNZ. The estimation techniques used for this analysis were SFA and DEA. Most of the data employed at the modelling stage is constructed using a number of assumptions, and thus their level of accuracy is uncertain; therefore, more weight should be placed on the results of the SFA models, given the technique's robustness to situations where there is uncertainty regarding data accuracy.

The adoption of SFA does not resolve the issue of data accuracy, but does mitigate it. Therefore, for the analysis to produce results that could be considered robust under the current uncertainty surrounding the data employed, extensive sensitivity analysis is undertaken. In total, the analysis uses no fewer than 17 SFA models, with each adopting three distributional specifications for the inefficiency component (only the specifications considered to be robust are counted here). The analysis also examined 24 DEA models, each of which produces efficiency estimates under a constant returns to scale (CRS) and a variable returns to scale (VRS) assumption, or an unconstrained and constrained CRS specification (for the models that use two separate inputs). The models are summarised below.

- Models using OPEX as the sole input estimated using SFA and DEA, with sensitivity analysis undertaken:
  - for the definition of OPEX (including and excluding marketing costs, as defined in section 3.1.2 and A1.1.2); and
  - the use of an alternative quantification methodology of LEC switched minutes (as presented in sections 3.3 and A1.3).

- Models using the constructed measure of 'total costs' (ie, the sum of OPEX and the constructed standardised 'depreciation' measure) as the sole input estimated using SFA and DEA, with sensitivity analysis undertaken:
  - for the definition of OPEX (including and excluding marketing costs, as defined in section 3.1.2 and A1.1.2); and
  - the use of an alternative quantification methodology of LEC switched minutes (as presented in sections 3.3 and A1.3).

- Models using OPEX and the constructed standardised 'depreciation' measure as separate inputs estimated using DEA, with sensitivity analysis undertaken:
  - for the definition of OPEX (including and excluding marketing costs as defined in section 3.1.2 and A1.1.2); and
  - the use of an alternative quantification methodology of LEC switched minutes (as presented in sections 3.3 and A1.3).

Model specification for the econometric (SFA) models

All econometric (SFA) models were developed using general-to-specific modelling. This approach begins with a general model that includes all the variables deemed by the researcher to be potentially significant, and starts removing, one at a time, those found to be statistically insignificant; the model is then re-estimated. This process is repeated until all variables remaining in the model are deemed to be statistically significant. During every step of the procedure, additional testing is undertaken to ensure that the models produced do not suffer from know statistical maladies that could affect the accuracy of the results (ie, heteroscedasticity, mis-specification, etc); outlier analysis is also implemented at each step to ensure that no single observation, or small group of observations, 'drives' (has an unduly large influence on the) estimated model parameters.

For each SFA model:

- two functional forms were examined—a Cobb–Douglas function and a more general translog cost function (the former being a more restricted version of the latter);

- three alternative distributional assumptions were used for the inefficiency term in the SFA models—a half-normal, truncated normal and exponential distribution.

All the econometric models used in the analysis are presented in detail in Appendix 2.

Model specification for the non-parametric (DEA) models

The DEA models were based on the developed econometric models—ie, access lines and switch minutes, the two main output measures, were used. For the DEA models:

- both CRS and VRS models were examined for the specifications that make use of a single input (ie, OPEX or a measure of 'total costs');

- that employ as separate inputs OPEX and the standardised 'depreciation' measure, only CRS are assumed. This is because, in order for these models to be considered robust, weight restrictions for the standardised 'depreciation' measure are required (see below);

- more complex models were also examined by including the number of business access lines, residential access lines and leased access lines as three separate outputs rather than the total number of access lines. The reason for this disaggregation of access lines is that different mixes of access lines are likely to affect an operator's cost base in different ways (ie, business access lines are likely to be more costly than residential access lines, especially when customer services, product services, sales and marketing are considered in the analysis, as is the case for this study).

In every case, the models adopt an input-minimisation orientation; thus, in the case of the VRS models, the effects of scale are captured by the mix of outputs. The models that use OPEX and the standardised 'depreciation' measure as separate inputs require weight restrictions in order to be considered robust. This is necessary given the way in which DEA works, which is by assigning relative weights to each input and output in order to arrive at aggregate measures of total input and total output, the ratio of which is used to derive an estimate of relative efficiency. The only restriction placed by the unconstrained DEA model is that the weights chosen by a comparator, when applied to the inputs and outputs of another unit, should not result in assessing that unit as more than 100% efficient. Therefore, to maximise its efficiency score when an input orientation is adopted, a unit could place most of the inputs' weight in a single input where it has a low value, relative to the other comparators, while completely ignoring the others. An example from this analysis can be found in TCNZ, which, when assessed by an unconstrained, multi-input DEA model, in most cases places more than 85% of its relative inputs' weight on the standardised 'depreciation' measure. If no additional constraints are placed on the model, the analysis is arguably inaccurate and inequitable.

The weight restrictions imposed to avoid this situation in effect limit the weight allocation to the standardised 'depreciation' measure, so that the virtual weight assigned to this measure should not exceed the 33% threshold. In other words, when the input weights are multiplied by the input values, the restriction will not permit the total weight of the standardised 'depreciation' to be more that one-third of the total weight of both inputs. This restriction is based on the ratio of the standardised 'depreciation' measure to the sum of OPEX and standardised 'depreciation', which is estimated to be approximately 33%.

Key to abbreviations used

The tables presented in the following sections and in Appendix 2 use abbreviations when describing the specifications of the models—see Table 4.1.

Table 4.1: Abbreviations used

Abbreviation	Description
Outputs	
lines	total access lines (sum of switched residential, business and other lines, and leased lines)
swminor	switched minutes, quantified using aggregate US average call duration (original definition)
swminalt	switched minutes, quantified using TCNZ's average call duration (alternative definition)
line2	translog cross-product of total access lines
swminor2	translog cross-product of switched call minutes (original definition)
line_swminor	translog cross-product of total access lines and switched call minutes (original definition)
swminalt2	translog cross-product of switched call minutes (alternative definition)
line_swminalt	translog cross-product of total access lines and switched call minutes (alternative definition)
sheath	length of sheath
lline_sheath	translog cross-product of total access lines and length of sheath
lswminor_sheath	translog cross-product of length of sheath and switched call minutes (original definition)
lines_swbus	switched business access lines
line_swres	switched residential access lines
line_ll	switched business access lines
Inputs	
opexacc	OPEX including marketing
opexmrk	OPEX excluding marketing
costov	sum of standardised 'depreciation' and OPEX including marketing
costalt	sum of standardised 'depreciation' and OPEX excluding marketing

Source: OXERA.

The application of SFA requires all variables included in the model to be presented in their natural logarithmic form. The notation used to distinguish the logarithmic form from the level form is the addition of *l* as a prefix to the variable name (eg, the natural logarithm of switched access minutes—original is *lswminor*).

The application of DEA does not require the transformation of any variable; therefore, all inputs and outputs are used in their level form.

4.1 OPEX

This section summarises the results from modelling operating costs only. Due to a required assumption on the appropriate proportion of sales and marketing costs relating to national calls to be included in TCNZ's cost base (see section 3.1.2 and above), sensitivity analysis was undertaken using two operating cost definitions: one including all sales and marketing cost for the LECs and a proportion of the national costs of such services for TCNZ (defined as OPEX including marketing costs); and the another excluding all sales and marketing costs for the LECs and all national sales and marketing costs for TCNZ (defined as OPEX excluding marketing costs).

In the tables that follow in the sub-sections below, specifications deemed not to be as robust as the bulk of those reported are shaded (comments are also included in the main text).

4.1.1 OPEX including marketing

SFA results

Table 4.2 summarises the results of the SFA of operating costs using Cobb–Douglas cost functions. In all models, TCNZ is assessed as being relatively inefficient, with a relative inefficiency score of between 16% and 25%. This would suggest a target cost-reduction range for TCNZ of 3.4–5.7% per annum over five years. (All of the developed models were assessed as robust.)

Table 4.2: Results of SFA Cobb–Douglas models

	Distribution	Outputs		Inefficiency (%)	Rank	Target cost reduction over five years (% pa)
A1.h	half normal	llines	lswminor	22.5	40	5.0
A1.e	exponential	llines	lswminor	15.8	39	3.4
A1.t	truncated normal	llines	lswminor	18.3	39	4.0
A2.h	half normal	llines	lswminalt	25.4	42	5.7
A2.e	exponential	llines	lswminalt	19.2	42	4.2
A2.t	truncated normal	llines	lswminalt	21.0	42	4.6

Source: OXERA analysis.

Table 4.3 summarises the results of the SFA of operating costs, using translog cost functions. Models A3.e and A3.h are not as robust as the bulk of the models reported (the SFA specification being valid only at approximately the 25% significance level). Ignoring these two models would suggest a target cost-reduction range for TCNZ of 4.6–6.5% per annum over five years.

Table 4.3: Results of SFA translog cost models

	Distribution	Outputs, excluding cross-product terms		Inefficiency (%)	Rank	Target cost reduction over five years (% pa)
A3.h	half normal	llines	lswminor	14.4	35	3.1
A3.e	exponential	llines	lswminor	7.8	34	1.6
A3.t	truncated normal	llines	lswminor	n.a.	n.a.	n.a.
A4.h	half normal	llines	lswminalt	28.5	44	6.5
A4.e	exponential	llines	lswminalt	21.2	44	4.6
A4.t	truncated normal	llines	lswminalt	23.0	44	5.1

Source: OXERA analysis.

Combining the results from the Cobb–Douglas and translog model specifications leads to an annual cost-reduction target over a five-year period for TCNZ in the range of 3.4–6.5%.

DEA results

Table 4.4 summarises the results of the DEA of operating costs.

Table 4.4: Results of DEA models

Returns to scale	Outputs		Inefficiency (%)	Target cost reduction over five years (% pa)
CRS	lines	swminor	28.3	6.4
VRS	lines	swminor	25.7	5.8
CRS	lines_swbus, line_swres, line_ll	swminor	25.4	5.7
VRS	lines_swbus, line_swres, line_ll	swminor	24.3	5.4
CRS	lines	swminalt	32.2	7.5
VRS	lines	swminalt	30.0	6.9
CRS	lines_swbus, line_swres, line_ll	swminalt	27.7	6.3
VRS	lines_swbus, line_swres, line_ll	swminalt	26.3	5.9

Source: OXERA analysis.

No counterintuitive allocation of weights was detected for TCNZ's outputs in the DEA models presented above. The models also presented fair discriminatory power, with the less discriminatory models assessing approximately 23% of the operators as efficient (the models in question are those using the disaggregated access lines measure based on a VRS assumption). Therefore, all models above can be considered robust. **The annual cost-reduction target over a five-year period for TCNZ derived from the single-input, OPEX including marketing, DEA models is in the range of 5.4–7.5%.**

4.1.2 OPEX excluding marketing

SFA results

Table 4.5 summarises the results of the SFA of OPEX excluding marketing using Cobb–Douglas cost functions. In all models, TCNZ is assessed as being relatively inefficient, with an implied target cost-reduction range for TCNZ of 5–7.4% per annum over five years. (All of the developed models were robust.)

Table 4.5: Results of SFA Cobb–Douglas models

	Distribution	Outputs		Inefficiency (%)	Rank	Target cost reduction over five years (% pa)
B1.h	half normal	llines	lswminor	28.6	44	6.5
B1.e	exponential	llines	lswminor	22.7	44	5.0
B1.t	truncated normal	llines	lswminor	25.2	44	5.6
B2.h	half normal	llines	lswminalt	32.1	45	7.4
B2.e	exponential	llines	lswminalt	27.2	45	6.2
B2.t	truncated normal	llines	lswminalt	28.8	45	6.6

Source: OXERA analysis.

Table 4.6 summarises the results of the SFA of operating costs, excluding marketing, using translog cost functions. Models B3.e and B3.h are not as robust as the bulk of the models reported (the SFA specification being valid only at approximately the 30% significance level). Ignoring these two models would suggest a target cost-reduction range for TCNZ of 7.1–7.3% per annum over five years.

Table 4.6: Results of SFA translog cost models

	Distribution	Outputs, excluding cross-product terms		Inefficiency (%)	Rank	Target cost reduction over five years (% pa)
B3.h	half normal	llines	lswminor	17.2	42	3.7
B3.e	exponential	llines	lswminor	10.0	42	2.1
B3.t	truncated normal	llines	lswminor	n.a.	n.a.	n.a.
B4.h	half normal	llines	lswminalt	35.0	47	8.3
B4.e	exponential	llines	lswminalt	30.6	48	7.1
B4.t	truncated normal	llines	lswminalt	31.5	48	7.3

Source: OXERA analysis.

Combining the results from the Cobb–Douglas and translog model specifications leads to an annual cost-reduction target over a five-year period for TCNZ in the range of 5–7.4%.

DEA results

Table 4.7 summarises the results of the DEA of operating costs.

Table 4.7: Results of DEA models

Returns to scale	Outputs		Inefficiency (%)	Target cost reduction over five years (% pa)
CRS	lines	swminor	38.2	9.2
VRS	lines	swminor	35.5	8.4
CRS	lines_swbus, line_swres, line_ll	swminor	35.1	8.3
VRS	lines_swbus, line_swres, line_ll	swminor	33.6	7.9
CRS	lines	swminalt	41.5	10.2
VRS	lines	swminalt	39.6	9.6
CRS	lines_swbus, line_swres, line_ll	swminalt	36.6	8.7
VRS	lines_swbus, line_swres, line_ll	swminalt	34.9	8.2

Source: OXERA analysis.

No counterintuitive allocation of weights was detected for TCNZ's outputs in the DEA models presented above. The models also presented fair discriminatory power, with the less discriminatory models assessing approximately 21% of the operators as efficient (the models in question are those that use the disaggregated access lines measure based on a VRS assumption). Therefore, all models above can be considered robust. **The annual cost-reduction target over a five-year period for TCNZ derived from the single-input, OPEX including marking, DEA models is in the range of 7.9–10.2%.**

4.1.3 Summary of the results of the OPEX modelling

Given that international comparisons are being undertaken, and the consequent data comparability uncertainties (as discussed in section 3), OXERA would suggest that more weight is placed on the SFA results of this section, which explicitly take into account noise, such as measurement errors in the data and the exclusion of important cost drivers. As such, by excluding the DEA modelling of operating costs, the OPEX analysis suggest that a possible **cost-reduction target range of 3.4–7.4% pa** when considering individual models, or a **narrower range of 4.7-6.6% pa** based on the point estimates provided for each broader sensitivity category (as summarised in Table 4.8)

Table 4.8: Summary results of operating cost models

Model	Target cost reduction (% pa)	
SFA model of operating costs including marketing	3.4–6.5	4.7
SFA model of operating costs excluding marketing	5.0–7.4	6.6
DEA model of operating costs including marketing	5.4–7.5	6.2
DEA model of operating costs excluding marketing	7.9–10.2	8.8

Source: OXERA analysis.

4.2 'Total cost'—the sum of OPEX and standardised 'depreciation'

4.2.1 'Total cost' including marketing

This section summarises the results of modelling the sum of operating costs including marketing and the standardised 'depreciation' measure.

SFA results

Table 4.9 summarises the results of the SFA of 'total costs' (as given by the arithmetic sum of operating costs and a standardised 'depreciation' figure) using Cobb–Douglas cost functions. In every case, TCNZ's efficiency estimate has improved; however, the accuracy of such results is highly suspect, given the standardised 'depreciation' measure lack of intuitive appeal, theoretical justification and accuracy.

Keeping the above caveats in mind, the implied target cost-reduction range for TCNZ is 1.1–2.7% per annum over five years. (All of the developed models were robust.)

Table 4.9: Results of SFA Cobb–Douglas models

	Distribution	Outputs			Inefficiency (%)	Rank	Target cost reduction over five years (% pa)
C1.h	half normal	llines	lswminor	lnshealth	12.7	17	2.7
C1.e	exponential	llines	lswminor	lnshealth	5.6	15	1.1
C1.t	truncated normal	llines	lswminor	lnshealth	6.2	17	1.3
C2.h	half normal	llines	lswminalt	lnshealth	12.8	19	2.7
C2.e	exponential	llines	lswminalt	lnshealth	6.7	18	1.4
C2.t	truncated normal	llines	lswminalt	lnshealth	12.9	19	2.7

Source: OXERA analysis.

Table 4.10 summarises the results of the SFA of 'total costs' (as given by the arithmetic sum of operating costs and a standardised depreciation figure), using translog cost functions. TCNZ is ranked somewhat lower on the basis of the translog models compared with the Cobb–Douglas cost function models. The implied target cost-reduction range for TCNZ is 1.5–3.3% per annum over five years. (All of the developed models were robust.)

Table 4.10: Results of SFA translog cost models

	Distribution	Outputs, excluding cross-product terms		Inefficiency (%)	Rank	Target cost reduction over five years (% pa)
C3.h	half normal	llines	lswminor	11.9	23	2.5
C3.e	exponential	llines	lswminor	7.5	25	1.5
C3.t	truncated normal	llines	lswminor	n.a.	n.a.	n.a.
C4.h	half normal	llines	lswminalt	15.5	27	3.3
C4.e	exponential	llines	lswminalt	10.0	31	2.1
C4.t	truncated normal	llines	lswminalt	15.7	27	3.3

Source: OXERA analysis.

Combining the results from the Cobb–Douglas and translog model specifications leads to an annual cost-reduction target over a five-year period for TCNZ in the range of 1.1–3.3% (but note the caveats presented at the beginning of this section).

DEA results

Table 4.11 summarises the results of the DEA of 'total costs', as given by the arithmetic sum of operating costs and the standardised 'depreciation' figure.

Table 4.11: Results of DEA models

Returns to scale	Outputs		Inefficiency (%)	Target cost reduction over five years (% pa)
CRS	lines	swminor	5.9	1.2
VRS	llines	swminor	3.6	0.7
CRS	lines_swbus, line_swres, line_ll	swminor	2.2	0.4
VRS	lines_swbus, line_swres, line_ll	swminor	1.7	0.3
CRS	lines	swminalt	14.2	3.0
VRS	lines	swminalt	12.9	2.7
CRS	lines_swbus, line_swres, line_ll	swminalt	5.3	1.1
VRS	lines_swbus, line_swres, line_ll	swminalt	4.4	0.9

Source: OXERA analysis.

No counterintuitive allocation of weights was detected for TCNZ's outputs in the DEA models presented above. The models also presented fair discriminatory power, apart from those using the disaggregated access lines measure and adopting a VRS assumption, in which more than one-third of the comparator group was assessed as fully efficient. However, given the similarities of the estimated efficiency results of these models under CRS and VRS assumptions, the analysis does not dismiss the results of these less discriminatory specifications. **The annual cost-reduction target over a five-year period for TCNZ derived from the single-input, 'total cost' measure, DEA models is in the range of 0.3–3%.**

Table 4.12 summarises the results of the DEA of total costs given by modelling operating costs and the standardised 'depreciation' figure as two separate inputs to allow for different rates of expenditure substitution for different companies. As discussed at the beginning of this section (section 4.1.2), when two separate inputs are included in these DEA models, the outcome can be that companies are assessed as being 100% efficient as a result of all the weight being placed on one input only. To avoid this inequitable result, constraints were included in the modelling such that the weight placed on OPEX should be at least twice that placed on CAPEX. Also, given that the adoption of linear constraints in a non-linear model (ie, one that adopts a VRS assumption) can be problematic, in both conceptual and computational terms, the modelling summarised below is for the CRS formulation only, indicating in the first column the inclusion or exclusion of the weight restriction.

Table 4.12: Results of DEA models with two separate inputs

Constraint	Outputs		Inefficiency (%)	Target cost reduction over five years (% pa)
No	lines	swminor	0.0	0.0
Yes	lines	swminor	15.1	3.2
No	lines_swbus, line_swres, line_ll	swminor	0.0	0.0
Yes	lines_swbus, line_swres, line_ll	swminor	11.7	2.5
No	lines	swminalt	0.0	0.0
Yes	lines	swminalt	13.0	2.7
No	lines_swbus, line_swres, line_ll	swminalt	0.0	0.0
Yes	lines_swbus, line_swres, line_ll	swminalt	3.6	0.7

Source: OXERA analysis.

When the unconstrained two-input DEA models were estimated, it was found that TCNZ reached a frontier position by applying between 77% and 98% of its total relative input weight to the standardised 'depreciation' measure (depending on the specification). Given this measure's lack of intuitive and theoretical appeal, together with its lack of accuracy, the results reached by such specifications are not considered robust and therefore an input weight restriction is imposed.

According to the constrained two-input DEA models, the annual cost-reduction target over a five-year period for TCNZ is in the range of 0.7–3.2%.

4.2.2 'Total cost' excluding marketing

This section summarises the results of modelling operating costs excluding marketing, combined with the standardised 'depreciation' measure.

SFA results

Table 4.13 summarises the results of the SFA of 'total costs' (as given by the arithmetic sum of operating costs excluding marketing and a standardised depreciation figure) using Cobb–Douglas cost functions. Excluding marketing leads to the deterioration of TCNZ's estimated efficiency score, which results in annual cost reductions over five years in the range 1.9–3.7%. (All of the developed models were robust.)

Table 4.13: Results of SFA Cobb–Douglas models

	Distribution	Outputs			Inefficiency (%)	Rank	Target cost reduction over five years (% pa)
D1.h	half normal	llines	lswminor	lnshealth	14.3	23	3.0
D1.e	exponential	llines	lswminor	lnshealth	9.3	24	1.9
D1.t	truncated normal	llines	lswminor	lnshealth	11.1	24	2.3
D2.h	half normal	llines	lswminalt	lnshealth	17.4	33	3.7
D2.e	exponential	llines	lswminalt	lnshealth	12.4	33	2.6
D2.t	truncated normal	llines	lswminalt	lnshealth	14.8	33	3.1

Source: OXERA analysis.

Table 4.14 summarises the results of the SFA of total costs (as given by the arithmetic sum of operating costs excluding marketing and a standardised depreciation figure), using translog cost functions. Model D3.e is not particularly robust (being valid only at around the 20% significance level). Ignoring this model would suggest a target cost-reduction range for TCNZ of 2.7–4.7% per annum over five years.

Table 4.14: Results of SFA translog cost models

	Distribution	Outputs, excluding cross-product terms		Inefficiency (%)	Rank	Target cost reduction over five years (% pa)
D3.h	half normal	llines	lswminor	12.9	22	2.7
D3.e	exponential	llines	lswminor	7	30	1.5
D3.t	truncated normal	llines	lswminor	n.a	n.a	n.a
D4.h	half normal	llines	lswminalt	21.2	41	4.6
D4.e	exponential	llines	lswminalt	15.4	42	3.3
D4.t	truncated normal	llines	lswminalt	21.3	41	4.7

Note: For the full specification of these models, see Appendix A2.4.3 and A2.4.4.
Source: OXERA analysis.

Combining the results from the Cobb–Douglas and translog model specifications leads to a annual cost-reduction target over a five-year period for TCNZ in the range of 1.9–4.7% (but note the caveats presented at the beginning of this section).

DEA results

Table 4.15 summarises the results of the DEA of total costs, as given by the arithmetic sum of operating costs and a standardised depreciation figure.

Table 4.15: Results of DEA models

Returns to scale	Outputs		Inefficiency (%)	Target cost reduction over five years (% pa)
CRS	lines	swminor	12.5	2.6
VRS	lines	swminor	10.6	2.2
CRS	lines_swbus, line_swres, line_ll	swminor	8.6	1.8
VRS	lines_swbus, line_swres, line_ll	swminor	7.9	1.6
CRS	lines	swminalt	19.2	4.2
VRS	lines	swminalt	18.6	4.0
CRS	lines_swbus, line_swres, line_ll	swminalt	11.2	2.3
VRS	lines_swbus, line_swres, line_ll	swminalt	10.1	2.1

Source: OXERA analysis.

No counterintuitive allocation of weights was detected for TCNZ's outputs in the DEA models presented above. The models also presented fair discriminatory power, apart from those that use the disaggregated access lines measure based on a VRS assumption, in which more than one-third of the comparator group was assessed as fully efficient. However, given the similarities of the estimated efficiency results of these models under CRS and VRS assumptions, the analysis does not dismiss the results of these less discriminatory specifications. **The annual cost-reduction target over a five-year period for TCNZ derived from the single-input, 'total cost' measure, DEA models is the range of 1.6–4.2%.**

Table 4.16 summarises the results of the DEA of total costs as given by modelling operating costs and the standardised ‘depreciation’ figure as two separate inputs. As discussed at the beginning of this section (section 4.1.2), when two separate inputs are included in these DEA models, the outcome can be companies being assessed as 100% efficient by placing all the weight on only one input. To avoid this inequitable result, constraints were included in the modelling such that the weight placed on OPEX should be at least twice that placed on CAPEX. Also, given that the adoption of linear constraints in a non-linear model (ie, one that adopts a VRS assumption) can be problematic, in both conceptual and computational terms, the modelling summarised below is for the CRS formulation only, indicating in the first column the inclusion or exclusion of the weight restriction.

Table 4.16: Results of DEA models with two separate inputs

Constraint	Outputs		Inefficiency (%)	Target cost reduction over five years (% pa)
No	lines	swminor	0.0	0.0
Yes	lines	swminor	10.8	2.3
No	lines_swbus, line_swres, line_ll	swminor	0.0	0.0
Yes	lines_swbus, line_swres, line_ll	swminor	6.9	1.4
No	lines	swminalt	0.0	0.0
Yes	lines	swminalt	18.0	3.9
No	lines_swbus, line_swres, line_ll	swminalt	0.0	0.0
Yes	lines_swbus, line_swres, line_ll	swminalt	9.5	2.0

Source: OXERA analysis.

When the unconstrained two-input DEA models were estimated, it was found that TCNZ reached a frontier position by applying between 80% and 98% of its total relative input weight to the standardised ‘depreciation’ measure (depending on the specification). Given this measure’s lack of intuitive and theoretical appeal, together with its lack of accuracy, the results reached by such specifications could not be considered robust by the analysis and therefore an input weight restriction is imposed.

According to the constrained two-input DEA models, the annual cost-reduction target over a five-year period for TCNZ is in the range of 1.4–3.9%.

4.2.3 Summary of the results of the ‘total cost’ modelling

In all models, TCNZ’s estimated inefficiency has improved compared with the operating cost models. If the standardised depreciation measure used in the analysis were deemed to be robust, this could suggest that TCNZ is able to provide comparable telecommunications services to the LECs using a smaller asset base, which could be considered a measure of efficiency. However, the standardised depreciation measure used for the modelling suffers from a number of shortcomings (see section 3.2 and A1.2). On the other hand, these results indicate that TCNZ is more efficient in using its asset base than the LECs, since although it cannot be maintained that the measure produces accurate results, the direction and the relative size of the difference should provide an *indication* of relative capital efficiency.

Table 4.17 summarises the results of the ‘total cost’ modelling.

Table 4.16: Summary results of 'total cost' models

Model	Target cost reduction (% pa)	
	Range	Point estimate (based on geometric mean of all models)
SFA model of total costs including marketing	1.1–3.3	2.1
SFA model of total costs excluding marketing	1.9–4.7	3.0
DEA model of total costs including marketing	0.3–3.0	1.0
DEA model of total costs excluding marketing	1.6–4.2	2.5
DEA two input model of operating costs including marketing, and standardised depreciation	0.7–3.2	2.0
DEA two input model of operating costs excluding marketing, and standardised depreciation	1.4–3.9	2.2

Source: OXERA analysis.

The question of data accuracy is still pertinent for the 'total cost' specifications, although the inclusion of a measure of capital expenditure (however lacking in appeal) creates additional theoretical concerns. These relate to the issue of substitution between the two inputs (see discussion in section 2.2). These issues can be tackled by the two-input DEA models. Therefore, given the combination of the theoretical factors of input substitution and the likely inaccuracy of the data employed, which is compounded by the use of the standardised 'depreciation', no estimate produced by these two approaches should be discarded outright. On the other hand, the results of the single input DEA model should carry less weight, given that the approach offers neither the separation of inefficiency from noise of the SFA approach nor a robust solution for the issue of input substitution of the two-input DEA models.

In any case, it is very unlikely that the estimated cost reduction ranges offer any degree of accuracy[61], apart as an indicator of TCNZ's likely superior efficiency in utilising its capital resources. Despite the overall lack of robustness of the 'total cost' results, this factor plays a major role in the conclusions of this study.

[61] When excluding the results of the single-input DEA models, the range of cost reductions based on the 'total cost' sensitivity analysis is 0.7–4.7% pa, with the point estimates providing the narrower range of 2–3%.

5. Conclusions

This study has examined the relative efficiency of TCNZ, using comparisons with the US LECs.

The first step was to examine the raw data and adjust it, where appropriate, to improve the comparability between TCNZ and the LECs. For example, where TCNZ undertakes activities not carried by the LECs, the costs associated with these activities were removed from TCNZ's cost base.

The next step was to compare the costs of TCNZ and the LECs, to assess whether TCNZ's actual costs appeared to be higher than would be expected of an efficiently operated company. In order to make like-for-like comparisons as far as possible, modelling techniques were employed which explicitly take into account differences in operating characteristics, such as the impact of size and economies of scale.

Given the level of data adjustments and assumptions required to undertake the modelling, significant sensitivity testing was also carried out. In addition, in order to improve the robustness of the conclusions, several alternative modelling approaches were adopted. Thus, the relative efficiency of TCNZ was estimated using two comparative-efficiency techniques (SFA and DEA). These models were developed first by undertaking econometric modelling of the relevant definition of cost, using a general-to-specific approach in order to identify robust parsimonious models. Then, additional statistical diagnostic testing was undertaken, combined with outlier analysis, to ensure the robustness of the developed models. Every model was examined to ensure that it provided intuitively signed and sized relationships between costs and cost drivers. Finally, these models were then used to assist in developing appropriate DEA models.

In addition to using two comparative-efficiency techniques, three alternative input definitions were employed (where appropriate):

- OPEX only, using SFA and DEA;
- OPEX and CAPEX as two separate inputs, using DEA; and
- a 'total cost' measure as the sole input, using SFA and DEA.

However, in comparative-efficiency exercises, the definition of CAPEX raises considerable problems, and is often not dealt with properly. This is because, although, in theory, the correct cost measure to use would be a measure of *economic* depreciation, in reality it is difficult to gather data to construct such a measure. Therefore, the analysis in this study was based on the accounting definition of depreciation. However, due to accounting differences, some standardisation process was required. Thus, the depreciation measure used was based on applying a consistent depreciation methodology to the replacement value of the asset base across the companies. Unfortunately, the methodology used to derive the replacement values of each company's asset base require such extensive assumptions that the resulting asset base cannot be considered to be a robust representation of a company's capital inputs.

Having undertaken significant SFA and DEA modelling, TCNZ's relative efficiency in each case was then derived by examining its position relative to the estimated frontier. A summary of the main results is provided in Table 5.1 below.

Table 5.1: Summary results of all models

Model	Target cost reduction (% pa)	
	Range	Point estimate (based on geometric mean of all models)
SFA model		
operating costs including marketing	3.4–6.5	4.7
operating costs excluding marketing	5.0–7.4	6.6
DEA model		
operating costs including marketing	5.4–7.5	6.2
operating costs excluding marketing	7.9–10.2	8.8
SFA model		
total costs including marketing	1.1–3.3	2.1
total costs excluding marketing	1.9–4.7	3.0
DEA model		
total costs including marketing	0.3–3.0	1.0
total costs excluding marketing	1.6–4.2	2.5
DEA two-input model		
operating costs including marketing, and capital costs	0.7–3.2	2.0
operating costs excluding marketing, and capital costs	1.4–3.9	2.2

Source: OXERA analysis.

Given the difficulties of quantifying CAPEX, OXERA considers that the results based on the OPEX specifications are the more satisfactory. However, the consequent inefficiency range from these models is tempered by the fact that TCNZ performs better on the 'total cost' model specifications, which suggests that TCNZ may be relatively more efficient on CAPEX (predicated on the accuracy of the estimation of capital costs). Thus, OXERA considers that a robust estimate for the potential cost reductions over a five-year period for TCNZ ranges between 2.5% and 5% per annum. This range is based on the lower end of the models that assess OPEX efficiency, which provide a range of 3.4-7.4% when the DEA specifications are excluded, and the middle point of the 'total cost' models, which provide a range of 2-3% when the single-input DEA specifications are excluded

As a final note, the results of this study represent the required savings TCNZ needs to achieve in order to reach efficient performance corresponding to the year 2000. In other words, they are a measure of static, or cross-industry, efficiency. Therefore, the resulting cost-reduction estimates do not incorporate likely cost reductions due to productivity improvements in the industry over time. The potential scope of these cost reductions, which are the result of overall technical and technological progress of the whole industry over time, could be quite significant; however, their estimation was beyond the remit of this study.

Appendix 1: Data Used in the Analysis

The LEC data used in the analysis was provided by the Federal Communications Commission (FCC) and was found on its website. The data forms part of the information submission that FCC requires the incumbent Local Exchange Carriers (LECs) to provide for the purposes of regulation, and are referred to as Statistics of Communications Common Carriers (SOCC). The relevant publication contains company-specific and industry-wide information on telecommunications costs, revenues, prices and usage, and has been one of the most widely used reference works in the field of telecommunications.

The data concerning TCNZ was either sourced from the relative efficiency report produced by PricewaterhouseCooper's Consulting (PwCC) on behalf of TCNZ[62] or provided to OXERA by the NZCC.

A1.1 Operating expenditure

A1.1.1LECs

Information relating to expenses can be found in tables 2-10 and 2-11 of the SOCC. Expense accounts are separated on the basis of the combined Big Three Expenses, which include the following accounts.

Table A1.1: Overview of the expense accounts used for the LECs

Big Three Expenses
Plant Specific Expenses
6210 Central Office Switching Expenses
6220 Operators Systems Expenses
6230 Central Office Transmission Expenses
6310 Information Origination/Termination Expenses
6410 Cable and Wire Facilities Expense
Plant Non-Specific Expenses
6530 Network Operations Expenses
Customer operations expenses
6610 Marketing
6620 Services

Source: FCC SOCC.

The above expense accounts were used to construct the operating cost base used in the comparative-efficiency analysis. The accounts that were excluded from the operating cost base and the reasons for their exclusion are detailed below.

[62] PwCC Consulting (2002), 'TCNZ Efficiency Study Based on Stochastic Frontier Analysis (SFA)', September.

6310 Information Origination/Termination Expenses

This expense account can be disaggregated into sub-categories, as shown in Table A1.2.

Table A1.2: Account no. 6310, Information Origination/Termination Expenses

6310	Information Origination/Termination Expenses
6311	Station Apparatus
6341	Large Private Branch Exchange
6351	Public Telephone Terminal Equipment
6362	Other Terminal Equipment

Source: FCC SOCC

The reason for the exclusion of this account was comparability with the information available for TCNZ. The cost data supplied by TCNZ excluded a category of costs termed CPE (customer premises equipment), which is the equivalent of the Information Origination/Termination Expenses found in the LEC accounts. The relevant assets were also excluded from the calculation of the depreciation charge used in the analysis for both TCNZ and the LECs. A second reason for the exclusion of the above cost category is the structure of private-line rentals. Station apparatus and large private branch exchange costs relate to the provision of leased line and closed-loop circuits, a service that does not seem to be provided by a number of LECs. This was verified first by the very small revenues reported by some LECs on their Local Private Line and Customer Premises Revenue accounts (accounts 5040 and 5050), and, second, by the wide variability of costs in this category observed across the LECs; the proportion of these costs relative to the final operating cost figure used for the analysis ranges from 2% to 22%.

6622 Number Services

This is a sub-category of the Services account that contains costs associated with the provision of customer number and classified listings. The reason for its exclusion was comparability with TCNZ's operating cost base, which excluded costs relating to the provision of directory services, and because the full details of this account for TCNZ were unknown.

Other excluded items

Although not included in the Big Three Expenses mentioned above, in constructing the operating cost base for the LECs the analysis did not include costs relating to access expenses (account no. 6540) and for the 'Provision for Uncollectible Notes Receivable' (account no. 6790). The reasons for the exclusion of said items are detailed below.

6540 Access expenses

The definition of access expenses given by the FCC is as follows:

> This account shall include amounts paid by interexchange carriers or other exchange carriers to another exchange carrier for the provision of carrier's carrier access.

This account was excluded from the analysis on the grounds that access costs, which are referred to in New Zealand as interconnect costs, represent rental payments made by the telecommunications operator in question to another operator for access to its network. In general, the issues relating to the provision of access to a telecommunications network are not straightforward.

Telecommunications networks provide a means of communicating with other end-users (including the ability to access data). In a monopoly communications market, end-users would naturally be connected to the same network. However, in a market of two or more players, end-users will not always be connected to the same network. Operators of communications networks therefore need to be physically and logically linked together—either directly or via a third party—to provide seamless conveyance of communications services across networks. The connection of communications networks is known as 'interconnection'. The charges for the conveyance of communications services across and between networks and for the physical connection to other networks are known as interconnection charges.

The relative size of interconnection charges is fundamental to the level of the retail price paid by the end-user. That price will include the costs incurred by the end-user's operator in providing the relevant telecommunications service (including retail costs, such as marketing), a profit element and any interconnection charge that the operator might have to pay to terminate the call on another operator's network. Given that interconnection charges relate to other operators' costs, and include a profit element, they should be considered as uncontrollable costs and thus removed from the analysis.

The exclusion of interconnection charges does not mean that the analysis does not take into account the costs incurred by the telecommunications operators for carrying calls on their networks, irrespective of the origination point of such calls.[63] These costs relate to the overall operation of the network and are thus included in the cost base (only access costs that the operator pays for the use of other operators' networks is excluded from the analysis).[64]

The issue of access is treated in this analysis by excluding the access expenses account (no. 6540) from the cost base of the assessed LECs. A similar treatment is applied to TCNZ's costs (see section A1.1.2).

6790 Provision for Uncollectible Notes Receivable

This account relates to a provision for doubtful debts (also known as bad debts). This account was excluded from the analysis on the basis that its size depends on regulatory decisions and the accounting systems adopted by the operators (which could also be determined by the regulator). Since the LECs and TCNZ operate under different regulatory environments and face different accounting frameworks, the analysis excludes accounts relating to the provision for bad debts from the cost base of *all* comparators, including TCNZ.

[63] As a reminder, the aim of this comparative-efficiency analysis is to measure the relative efficiency of the telecommunications operators in providing the relevant services that make the exchange of voice or data services over a fixed-line network possible.

[64] The telecommunications operator is compensated for providing access over its network by interconnection payments received, which theoretically should cover the 'engineering' cost of providing such access. However, although the whole issue of access charging is central to telecommunications regulation, the balance between interconnection outpayments and revenues is not relevant for this analysis.

6610 Marketing, excluded in some models as a form of sensitivity analysis

In some of the alternative modelling exercises, this account is excluded from the operating cost base of the LECs as a form of sensitivity analysis. The reason for this is TCNZ's request that all sales and marketing relating to national calls be excluded. Sales and marketing expenses for national calls amount to [✂]. The relevant weighted average value for the LECs is 7%. It appears that the relative size of the total sales and marketing expenses in the USA is comparable with that of the national sales and marketing expenses in New Zealand. Since the LECs' sales and marketing expenses are not broken down into local and intraLATA calls, some sensitivity analysis is undertaken, where sales and marketing costs (relating to specific products and not general brand marketing) are removed from the LECs' operating cost base, and sales and marketing costs for national calls are also removed from TCNZ's operating cost base.

A1.1.2TCNZ

The available accounting information relating to operating costs for TCNZ was not as detailed as that available for the LECs. One of the most significant constraints for this analysis was that the accounting information for TCNZ was not compatible with the framework of the LEC accounts, and was at a significantly higher level of aggregation. Another shortcoming was the lack of precise definitions regarding the cost categories used; the same applies to the allocation policies employed to arrive at the cost figures in question. Therefore, although an examination of the relative size of the cost figures provided has identified some counterintuitive values, this may be due to OXERA's not having access to precise definition for the accounting categories used by TCNZ.

In more detail, TCNZ's OPEX is divided into two major categories: Network OPEX, and Sales and Services OPEX. For each category, TCNZ provided a disaggregation of costs into the following categories:

Access/Local
National
International
Calls to Mobile
Leased Lines National
Leased Lines International
Other Data
CPE
Message/Smart
Interconnect
Other services, mobile, directory etc

Network OPEX

In its data submission, TCNZ suggested that a number of cost categories would need to be excluded from the analysis for reasons of comparability with the LECs. The suggested cost categories and relevant values to be excluded were based on analysis previously undertaken by PwCC. Table A1.3 presents the submitted information.

Table A1.3: Network OPEX account (NZ$)

Network OPEX	Total	Included	Excluded
Access/Local	[✄]	[✄]	[✄]
National	[✄]	[✄]	[✄]
International	[✄]	[✄]	[✄]
Calls to Mobile	[✄]	[✄]	[✄]
Leased Lines National	[✄]	[✄]	[✄]
Leased Lines International	[✄]	[✄]	[✄]
Other Data	[✄]	[✄]	[✄]
CPE	[✄]	[✄]	[✄]
Message/Smart	[✄]	[✄]	[✄]
Interconnect	[✄]	[✄]	[✄]
Other services, mobile, directory etc	[✄]	[✄]	[✄]
Total	[✄]	[✄]	[✄]

Source: TCNZ.

OXERA's understanding of what these accounts represent and whether they should be excluded from the analysis (either wholly or in some proportion) is summarised in Table A1.4 (changes are highlighted).

Table A1.4: Network OPEX account (NZ$)

Network OPEX	Total	Included	Excluded
Access/Local	[✂]	[✂]	[✂]
National	[✂]	[✂]	[✂]
International	[✂]	[✂]	[✂]
Calls to Mobile	[✂]	[✂]	[✂]
Leased Lines National	[✂]	[✂]	[✂]
Leased Lines International	[✂]	[✂]	[✂]
Other Data	[✂]	[✂]	[✂]
CPE	[✂]	[✂]	[✂]
Message/Smart	[✂]	[✂]	[✂]
Interconnect	[✂]	[✂]	[✂]
Other services, mobile, directory etc	[✂]	[✂]	[✂]
Total	[✂]	[✂]	[✂]

Source: TCNZ and OXERA analysis.

Detailed explanations of the allocations in Table A1.4 are provided below.

Access/Local

TCNZ suggested that all access/local costs should be included in the analysis. However, discussions with TCNZ revealed that the data provided included a category of outpayments relating to interconnection charges for local calls and toll bypass calls. According to OXERA's treatment of access costs, and to maintain comparability with the LECs, these items were removed from TCNZ's cost base.

The total value of this adjustment reduced TCNZ's cost base by [✂].

National

According to TCNZ, only [✂] of the total costs relating to the national calls account need to be excluded from the analysis. A data clarification request from TCNZ revealed that the cost figure excluded relates to costs incurred in handling emergency calls. The justification for excluding this item was that these costs are not incurred by the LECs, which, to OXERA's knowledge, is a valid point.

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

International

TCNZ suggested that the bulk of this account should be removed from the analysis. Further discussion revealed that the proportion of costs to be excluded relates to interconnection payments made by TCNZ to international telecommunications operators. Given OXERA's treatment of access costs, and for consistency with the LECs, this adjustment appears appropriate.

However, there is some ambiguity in the definition of this account. The provision of international call services requires use of the local network (as the international call passes from the international exchange to the local exchange, and vice versa); thus, a proportion of the costs relating to local network access would be expected to be included in this account. If the proportion of international calls costs that TCNZ suggested should be included in the analysis is assumed to recover the costs relating to the use of the local network, they appear to represent too small a proportion of the total cost of this account. This finding was based on further analysis, which revealed that these costs represent approximately [✂] of the Local/Access account, while the proportion of international switched minutes is [✂] of total switched minutes. This discrepancy between costs and usage raises doubts regarding the accuracy of the figure included in TCNZ's cost base.

Nevertheless, TCNZ is 'given the benefit of doubt'. Moreover, since the relative size of the cost item to be included is small, no adjustment regarding this figure was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Calls to mobile

The cost figure that TCNZ requested to be excluded from the analysis relates to interconnection charges paid by TCNZ to mobile operators for the termination of calls originating from the fixed network. According to the access treatment adopted, and for consistency with the LECs, these costs need to be removed from the analysis.

However, as is the case for international calls, it would be expected that at least a proportion of costs relating to this category should be included in the analysis, in order to cover the costs incurred by the use of the local network. No such adjustment is apparent in the accounts provided by TCNZ.

Nevertheless, TCNZ is given the benefit of doubt and no adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Leased lines national

All costs relating to this account are included in the analysis. Since leased-line services are also provided by the LECs, this treatment is considered appropriate.

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Leased Lines International

All costs relating to international leased lines are removed from the analysis. Since, in the USA, international leased line services are wholly provided by the international exchange carriers (the LECs are directly prohibited by the FCC from providing such services), the exclusion of such costs is justifiable

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Other data

TCNZ requested the exclusion of such costs due to PwCC advising the company that 'information on data services (other than leased lines) is not included in the LEC data and should hence be excluded from TCNZ data for consistency'. However, research conducted by OXERA for this analysis revealed that the LECs provide a wide range of data services, including both ISDN and xDSL (ie, high-speed services). An examination of the LEC accounting definitions also revealed no reference to excluding a proportion of costs relating to the Big Three Expenses that relate to the provision of such services.

Therefore, this cost category is included in OXERA's analysis, which serves to increase the operating cost base of TCNZ by [✂].

CPE (customer premises equipment)

For consistency with the LECs, this item was excluded from TCNZ's cost base (see the discussion in A1.1.1).

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Message/Smart

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Interconnect

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Other services, mobile, directory etc

TCNZ suggested that all costs relating to this category should be excluded from the analysis. However, an examination of the equivalent account in sales and services OPEX identified a number of sub-categories (relating to securing interconnect revenue, other revenue and error product) that describe activities undertaken by the LECs. Therefore, to ensure like-for-like comparisons, the costs incurred by TCNZ in undertaking these activities should be included in the analysis.

However, a full breakdown for 'other services, mobile, directory etc' under Network OPEX was not available, as was the case for the Sales and Services category. To overcome this problem, the analysis assumes that the same sub-categories found under the Sales and Services OPEX apply for Network OPEX as well, and, therefore, the same proportion of costs which were included in TCNZ's cost base in the Sales and Services OPEX category is included for Network OPEX as well. This proportion is estimated to be approximately [✂] of the total 'Other services, mobile, directory etc' account in the Sales and Services OPEX, and thus the same proportion is re-included for the Network OPEX category as well. (This proportion was derived without taking into account the sub-category of 'Business sustaining costs'.)

A proportion of this cost category is included in the analysis, increasing TCNZ's operating cost base by NZ$9,976,669.

Sales and Services OPEX

In its data submission TCNZ suggested that a number of cost categories would need to be excluded from the analysis for reasons of comparability with the LECs. The suggested cost categories and relevant values to be excluded were based on analysis previously undertaken by PwCC. Table A1.5 presents the submitted information.

Table A1.5: Sales and Services OPEX account (NZ$)

	Total OPEX[1]	Included in CE	Excluded from CE
Access/Local	[✂]	[✂]	[✂]
National	[✂]	[✂]	[✂]
International	[✂]	[✂]	[✂]
Calls to Mobile	[✂]	[✂]	[✂]
Leased Lines National	[✂]	[✂]	[✂]
Leased Lines International	[✂]	[✂]	[✂]
Other Data	[✂]	[✂]	[✂]
CPE	[✂]	[✂]	[✂]
Message/Smart	[✂]	[✂]	[✂]
Interconnect	[✂]	[✂]	[✂]
Other services, mobile, directory etc	[✂]	[✂]	[✂]
Total	[✂]	[✂]	[✂]

Note:[1] Total OPEX after the allocation of Business sustaining costs (ie, values include business sustaining costs).
Source: TCNZ.

While more extensive information was made available, compared with the Network OPEX account, the available information still does not approach the level of detail available for the LECs. OXERA therefore had to make some assumptions regarding certain cost definitions and the treatment of some cost categories.

OXERA's understanding on what these accounts represent and whether they should be excluded from the analysis (either wholly or in some proportion) is summarised in Table A1.6 (changes are highlighted).

Table A1.6: Sales and Services OPEX account (NZ$)

		Including marketing costs		Excluding marketing costs (sensitivity)	
	Total OPEX[1]	Included in CE	Excluded from CE	Included in CE	Excluded from CE
Access/Local	[✂]	[✂]	[✂]	[✂]	[✂]
National	[✂]	[✂]	[✂]	[✂]	[✂]
International	[✂]	[✂]	[✂]	[✂]	[✂]
Calls to Mobile	[✂]	[✂]	[✂]	[✂]	[✂]
Leased Lines National	[✂]	[✂]	[✂]	[✂]	[✂]
Leased Lines International	[✂]	[✂]	[✂]	[✂]	[✂]
Other Data	[✂]	[✂]	[✂]	[✂]	[✂]
CPE	[✂]	[✂]	[✂]	[✂]	[✂]
Message/Smart	[✂]	[✂]	[✂]	[✂]	[✂]
Interconnect	[✂]	[✂]	[✂]	[✂]	[✂]
Other services, mobile, directory etc	[✂]	[✂]	[✂]	[✂]	[✂]
Total	[✂]	[✂]	[✂]	[✂]	[✂]

Note: [1] Total OPEX after the allocation of Business sustaining costs (ie, values include business sustaining costs).
Source: TCNZ and OXERA analysis.

Detailed explanations of the allocations in Table A1.6 are provided below.

Access/Local

According to TCNZ all Access/local costs need to be included in the analysis. The analysis undertaken in this study assumes that this treatment is appropriate. (However, no access payments are included in Sales and Services costs—all access payments are incorporated in network access costs.)

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

National

The proportion of costs relating to national costs that TCNZ suggested be removed from the analysis relate to marketing and sales costs and billing costs for such calls. The analysis assumes that the allocation of such costs between local, national and international services has been robustly implemented, although the proportion of national marketing and sales costs to total operating costs (excluding access costs) for TCNZ is very close in size to the proportion of **total** marketing and sales costs to total operating costs for the LECs (see A1.1.1 for full details). Because of this similarity, extensive sensitivity analysis has been undertaken for the purposes of this study by removing sales and marketing costs from the cost base of both TCNZ and the LECs.

The ‘original’ definition of OPEX used in this study, however, does not exclude the full proportion of such costs from TCNZ’s cost base, as Table A1.6 demonstrates. This is due to comparability reasons with the LECs; although these telecommunications operators do not provide national calling services under the wide definition adopted by TCNZ, they do provide some long-distance call services. The following attempts to clarify the reasoning behind this adjustment.

The LECs provide three types of call service: local, intra-LATA[65] and inter-LATA. Local calls for the LECs are directly comparable with those of TCNZ (at least when a measure of switching complexity is taken into account). Inter-LATA calls are passed through a LEC’s local network to exchange facilities controlled by an IXC (inter-exchange carrier), and are therefore not the focus of this analysis (at least after the call has been switched from the local loop to the IXC point-of-presence). By contrast, Intra-LATA calls are akin to the definition of national calls used by TCNZ, in that these calls leave the local calling area (LCA) switched by the same LEC-owned local exchange to the local exchange of the terminating end of the call. They are then switched through the terminating local loop and are finally terminated by the same LEC. As such, all parts of an intra-LATA call are handled by the same LEC, which also incurs all the relevant costs. (The exception is where a competitor company operates its own local loop or toll bypass facilities. However, in such a case, some access costs are incurred, which are controlled for in this analysis by their removal from the cost base of both the LECs and TCNZ).

The existence of intra-LATA calls implies that the complete exclusion of sales and marketing costs and billing costs relating to TCNZ’s national calls is not appropriate. The treatment adopted for this analysis is to include a proportion of the excluded costs equal to the proportion of intra-LATA calls to all long-distance calls handled by the LECs (ie, the sum of intra-LATA and inter-LATA calls). This proportion was estimated US-wide to be 15.25%.

Given that this adjustment may not be very accurate, OXERA undertook sensitivity analysis in the modelling stage of this study by using two definitions of OPEX: the first includes all sales and marketing costs for the LECs and the above proportion of the relevant costs for TCNZ (the columns marked as ‘including marketing costs’ in Table A1.6); the second definition excludes such costs from the LECs’ cost base and excludes the available values for national sales, marketing and billing expenses from TCNZ’s operating cost base.

The adjustment proposed by OXERA increases TCNZ’s operating cost base by [✂].

[65] LATA is defined as ‘local access and transmission area’ and denotes the geographical area where a certain LEC is allowed to provide telephony services.

International

According to TCNZ, the bulk of this account should be removed from the analysis. Although there is some ambiguity about the definition of this account (refer to earlier discussion for network OPEX), **no adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).**

Calls to mobile

According to TCNZ, the bulk of this account should be removed from the analysis. Although there is some ambiguity about the definition of this account (refer to earlier discussion for network OPEX), **no adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).**

Leased lines national

All costs relating to this account are included in the analysis. Since leased-line services are also provided by the LECs, this treatment is considered appropriate.

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Leased lines international

All costs relating to international leased lines are removed from the analysis. Since, in the USA, international leased-line services are wholly provided by the international exchange carriers (the LECs are directly prohibited by the FCC from providing such services), the exclusion of such costs is justifiable.

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Other data

TCNZ suggested the exclusion of such costs due to PwCC advising the company that 'information on data services (other than leased lines) is not included in the LEC data and should hence be excluded from TCNZ data for consistency.' However, research conducted by OXERA for this analysis revealed that LECs provide a wide range of data services, including both ISDN and xDSL (ie, high-speed services). An examination of the LEC accounting definitions also revealed no reference to the exclusion of a proportion of costs that relate to the provision of such services.

This cost category is included in the analysis, which serves to increase the operating cost base of TCNZ by [✂].

CPE (customer premises equipment)

For consistency with the LECs, this item was excluded from TCNZ's cost base (see the discussion in A1.1.1).

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Message/Smart

No adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands).

Interconnect

Interconnect costs are not allocated to Network OPEX and, therefore, **no adjustment regarding this account was made in OXERA's analysis (TCNZ's treatment was adopted as it stands)**.

Other services, mobile, directory etc

Initially, TCNZ suggested that all costs relating to this category should be excluded from the analysis. When asked to provide more detail on the sub-categories of costs included in this account, TCNZ discovered in collating the necessary data that there had been some misallocation of costs in this account. The 'Other services, mobile, directory etc' account included a substantial cost item ([✂]) relating to 'Business sustaining costs', which are defined by TCNZ as 'a bucket of common costs associated with sales and marketing'. The full breakdown of this account is provided in Table A1.7.

Table A1.7: Sales and Services: 'Other services, mobile, directory etc' OPEX account

Sales and Services 'other costs'	Costs NZ$
CBA RAS Services	[✂]
Mobile/Cellular	[✂]
Mobile/Paging	[✂]
Mobile/Mobile	[✂]
Mobile/Airdata	[✂]
Mobile Group	[✂]
Mobile/Other	[✂]
Interconnect Revenue	[✂]
Other Revenue	[✂]
Directories	[✂]
Error Product	[✂]
Business Sustaining Costs	[✂]
Total	[✂]

Source: TCNZ.

TCNZ acknowledged that the 'Business sustaining costs' category needed to be included in the analysis and suggested that the relevant costs be allocated across the different product categories on the basis of each product group's directly attributable costs. The analysis has since adopted this suggestion.

A further clarification from TCNZ provided a summary breakdown of the 'Business sustaining costs' category, which reveals that the most significant proportion of these costs relates to customer services, billing, sales and marketing activities. Therefore, another possible treatment of this account could be to include the costs corresponding to the above categories directly, instead of opting for an allocation approach. This would serve to increase TCNZ's cost base by [✂]. However, this form of sensitivity analysis **was not implemented**, due to time constraints.

Also included in the 'Other services, mobile, directory etc' category are a number of smaller items that TCNZ suggested should be excluded (see Table A1.7). However, it would make intuitive sense that costs for securing interconnect revenue and other revenue, as well as error product accounts,[66] are also incurred by the LECs and should thus be included in the analysis. These costs represent approximately [✂] of the total 'Other services, mobile, directory etc' account, once the sub-category of 'Business sustaining costs' has been taken out. Therefore, the costs relating to these categories should be included in TCNZ's operating cost base.

[66] According to OXERA's understanding, the error product account includes costs that have not been allocated to the appropriate categories, but should have been. This could be due to rounding errors, or allocation methodology issues.

Thus, two adjustments were made to the 'Other services, mobile, directory etc' account:

- **TCNZ's operating cost base is increased by [✂]—ie, the amount of costs from the business sustaining costs category allocated to the categories that are included in the analysis. This is consistent with the allocation method suggested by TCNZ;[67] and**

- **TCNZ's operating cost base is increased by [✂]—in relation to interconnect revenue, other revenue and error product cost.**

A1.2 Capital expenditure

A number of issues arise in constructing an appropriate CAPEX measure to be included in the analysis and the appropriate method for its assessment, as section 2 serves to demonstrate. Section 2 concluded that a possible CAPEX measure for the analysis could be standardised depreciation, which could be based on standardised asset replacement values and a uniform depreciation profile for each asset category. However, the construction of a robust measure of CAPEX for the comparative-efficiency analysis has not been possible owing to the inability of the analysis to evaluate robustly the asset base of the LECs. Despite this, this study did use the asset valuation methodology proposed by TCNZ (and previously used by Oftel) to construct a standardised depreciation measure, which was later used in some of the sensitivity analysis. The methodology and OXERA's concerns are detailed below.

The aim of the methodology is to convert the asset values found in the companies' accounts—reported using historic-cost accounting standards—into their current-cost accounting (CCA) equivalents. It tries to achieve this by using the following formula:

$$\frac{CCA}{HCA} = ((1+I_a)*(1+I_g))^{[(1-NBV/GBV)/D]} \qquad \text{Equation A1.1}$$

where:

- CCA = the value based on current-cost accounting;
- HCA = the value based on historic-cost accounting;
- NBV = the net book value;
- GBV = the gross book value;
- I_a = real telecommunications-specific inflation (%);
- I_g = the general inflation rate of New Zealand or the USA;
- D = the weighted average of depreciation percentage over the asset categories.

[67] The OPEX figures presented in Tables A1.5 and A1.6 have already included this adjustment.

To make the above more intuitive, *[(1–NBV/GBV)/D]* could be substituted by *a*, where *a* is the average age of the asset category.

The data supplied by FCC for the LECs includes neither net book asset values nor average asset ages per asset category. Therefore, TCNZ, in its original study, applied its own average asset age to the formula used to convert the LEC asset values. Also, since no estimates of telecommunications-specific inflation rates were available for the LECs, TCNZ's estimates were used for the same reason.

The application of TCNZ's average asset age to the LECs' asset profiles—and, to a lesser degree, the telecommunications-specific inflation rates—defeats the whole purpose of the methodology, and leads to a measure that has little meaning when used to assess cost efficiency. The application of this treatment implicitly assumes that TCNZ and *all* the LECs are in the same position in their business and investment cycles, since it assumes that the asset ages of TCNZ and the LECs are the same and that the mix of assets (which is used to derive the average telecommunications-specific inflation rate) in each asset category is the same for both LECs and TCNZ. These assumptions **will** introduce bias into the analysis, in the following two ways.

- Some of the LECs will have an asset base that is older than TCNZ. By applying TCNZ's average asset age to the formula for calculating the CCA to HCA ratio, the CCA asset values will be overstated (since the exponent used, which should be equal to the assets' average age, will be smaller than its true value). This will lead to an overstatement of the standardised depreciation measure, which in turn will result in an understatement of the LEC's efficiency estimate. The reverse holds for LECs with asset bases that are newer than that of TCNZ.

- The mix of the assets available in each category will depend on several factors; there are examples where a telecommunications operator has opted to install relatively inexpensive assets that incur high maintenance costs. The choice of technology will also depend on the needs of the portion of the network to which this technology relates. The rate of take-up of new technologies will also influence the asset mix of each company. All of the above choices are endogenous to the assessed operator, and can be considered as sources of efficiency (or inefficiency). The application of a single, aggregate telecommunications-specific inflation rate will remove all the variability in the comparator set that is due to these choices.

The above discussion should help to point out the methodology's severe reliance on TCNZ's values. This reliance makes the resulting depreciation estimates less representative of the actual capital consumption over the assessed period. This makes the efficiency estimates that also include this measure in the estimation less reliable. Nevertheless, and despite its limitations, sensitivity analysis that makes use of the constructed standardised 'depreciation' measure is undertaken in this study.

A further question that needs to be considered is how to use the constructed CAPEX measure in the analysis. Since this measure is expressed in monetary terms, TCNZ suggested that the appropriate approach would be to add it to OPEX in order to arrive at a measure of total costs. However, this treatment would mean that OPEX and CAPEX can be substituted on a one-to-one basis, which is counterintuitive (see the discussion in section 2). A more robust approach would be to include the CAPEX measure separately in the analysis, which is possible through the use of DEA. Although the aggregation to a single-cost-measure approach is not theoretically justifiable, this study has implemented extensive sensitivity analysis using this measure as well.

The asset categories for both TCNZ and LECs that were used to construct the depreciation measure are presented in Table A1.8.

Table A1.8: Asset categories

Asset categories
Total Land and Support Assets
Total Central Office Switching
Operator Systems
Total Central Office Transmission
Total Information Origination/Termination
Total Cable and Wire Facilities

The only excluded category for the LECs (and TCNZ) is ‘Total Information Origination/Termination systems’. This was excluded for reasons of balance between OPEX and CAPEX, the high variability of its values (mentioned above in A1.1), and finally for consistency with TCNZ’s accounts.

The comparability problems of the accounting systems encountered with OPEX were absent in the case of CAPEX because TCNZ supplied asset information that was mapped directly onto the LEC accounting system. The only exception to this were two asset accounts for TCNZ termed ‘Other data equipment’ and ‘Leased service equipment’, which are excluded from the analysis. Although the comparable OPEX items are included in TCNZ’s cost base, the CAPEX items relating to the provision of data services are excluded from the analysis, as per TCNZ’s original data submission, because no direct correspondence exists to the LEC accounts and therefore neither a telecommunications-specific inflation nor an average asset age estimate is available for those items. However, their exclusion from TCNZ’s cost base violates the balance between the different types of input used and between the inputs and outputs of the analysis. The theoretically correct treatment would therefore be for them to be included in the analysis. The effect of their inclusion could be significant in relation to the estimated efficiency scores resulting from the ‘total cost’ models, since they represent approximately [✂] of TCNZ’s total asset base (under both the historic-cost and net-book-value definitions).

Currency conversion

Given the international nature of the analysis, the issue of adopting an equitable methodology for the implementation of currency conversion is pertinent. The approach adopted in most comparative-efficiency studies based on comparators from different countries is to use a mixture of PPP and exchange rates. The reasoning behind this treatment is that PPPs are more appropriate when considering assets or services traded in the domestic market, while exchange rates are more suitable for those traded in the international market. This separation of domestic and international traded assets and services is not without its issues; in addition, there are problems regarding the estimation of PPPs, which do not allow great confidence to be placed in the measure. However, previous academic studies that tested the sensitivity of the estimated efficiency results when both of these measures are used revealed that the effect of substituting PPPs with exchange rates as the means of currency conversion has an insignificant impact on the estimates. Therefore, this approach was adopted for this analysis as well.

Cost separability

The issue of cost separability is only touched upon in this study, given the fact that little can be done to correct for any bias that might be introduced.

Cost separability is an economic concept based on the idea that, where a unit produces multiple outputs, that unit might be able to achieve some economies in producing these outputs, simply due to its multiple output set. Thus, for the unit to minimise the cost of producing an output, it must produce that output as part of a set of multiple outputs and not in isolation. The reason why separability might be important in this analysis is that TCNZ provides a number of services in addition to those provided by the LECs, in the form of mobile and international calls. These additional services should be considered as additional outputs, and economic theory suggests that there are likely to be economies of scope in producing these outputs—particularly in this case of Sales and Services costs, such as corporate functions, billing and marketing.

However, given that the existence of such possible economies of scale cannot be empirically proven or estimated with the available data, this study assumes that the cost of providing these different services is separable, and no adjustment is made to TCNZ's cost base.

A1.3 Operational characteristics

The overall number of the operating characteristics that were considered in the analysis and their level of detail were constrained by the amount of available information. In this instance, the constraint was imposed by the available LEC data, which does not include the level of detail necessary for the implementation of an advanced, top-down comparative-efficiency exercise. Therefore, in almost every circumstance, some adjustments to the available primary data needed to be undertaken, in order to ensure comparability between TCNZ and the LECs.

A1.3.1Access lines

Access lines are potentially important in the analysis because they provide a measure of the company's customer base and thus the scale of its network. Access lines can be divided into two major categories: switched and leased access lines. The difference between them is that switched access lines connect the end-user's interface (eg, modem or telephone) with the local exchange, which then switches (directs) the call to its destination (either final or intermediate), while leased access lines connect to end-users exclusively and thus require no switching.

One category of leased access lines (64k-equivalent intra-LATA leased lines) is not reported by the LECs. In TCNZ's original analysis, this missing figure was estimated based on the revenue received for the provision of leased-line access. Although this treatment could be considered justified, the analysis undertaken for this report did not make use of it, mainly because the analysis uses a significant number of assumptions already, and there would be little gain in accuracy by burdening the estimation procedure with one more. Moreover, for most LECs, the revenue received due to private local access lines represents a very small proportion of their total revenue (ranging from 0% to 7%, with most LECs reporting values closer to 2–3%). Therefore, an adjustment in the number of leased access lines based on revenue would probably have had a minor impact. Consequently, the analysis assumes that no LEC provides local private-line services—this will be beneficial to TCNZ's final efficiency estimate since it reduces the output of its comparators.

The analysis undertaken for this study considers each category of access lines separately, but also tests whether the aggregation into a single measure is appropriate. In more detail, the analysis tests for whether the impact on costs is significant when the following categories are included:

- switched access lines, residential;
- switched access lines, business;
- switched access lines, other;
- switched access lines, total;
- leased access lines;
- total access lines.

A1.3.2Number of calls

The number of calls being routed through the fixed-line network could also be a significant factor for explaining costs, given that this measure represents network traffic. However, its appropriateness as a measure of traffic density could be quite low because it does not take into account the 'volume' of the network a call occupies.

Calls in New Zealand and Europe are divided into three broad categories: local, national and international. The handling of a call from each of these categories requires a different level of network utilisation; local calls are usually easier to handle, while long-distance calls could take up more network capacity. In comparative-efficiency exercises in the telecommunications industry, it is common practice to use the number of switches a call would occupy to be successfully handled as a proxy for the 'complexity' of each call. This subject is examined in greater detail in the next section.

Even though the 'number of calls' measure is not likely to be used as such in the final cost models (although, during the model formulation stage of this study, tests for its inclusion, in terms of its statistical validity, are undertaken), the accuracy of this measure is a significant issue since the 'number of calls' is used to construct the 'call minutes' variable.

When examining the LECs' accounting definitions, it was discovered that the number of local calls reported by the LECs includes both answered and unanswered calls, while the 'number of local calls' figure available for TCNZ includes only answered calls. Therefore, it is deemed necessary to scale down the LEC figures because using them as they stand results in artificially increasing one of the LECs' outputs, and hence reduces the accuracy of the resulting efficiency estimates. Since no estimate of the percentage of answered calls was available for the LECs, the percentage of such calls from TCNZ (76%) was used instead.

For the purposes of model formulation, the 'number of calls' variables considered are:

- number of local calls;
- number of other calls;
- total number of calls.

A1.3.3Call minutes

The call minutes factor for the LECs was also not directly available, since FCC requires the LECs to report only the number of calls. This factor was therefore constructed based on estimates of average call duration.

Call minutes are divided into local, national and international for TCNZ and local, intra-LATA and inter-LATA for the LECs, with the sum of inter- and intra-LATA calls being defined as long-distance (LECs do not provide international calling services and inter-LATA calls are partly handled by inter-exchange carriers). Local calling areas differ in size across both companies and countries, and long-distance calls require different numbers of switching and transmission stages. The use of unadjusted calling minutes is therefore not entirely suitable for a comparative-efficiency analysis, especially one based on international comparisons. One way of getting around this problem is to convert call minutes into switch minutes. Switch minutes take into account the number of switches a call passes through, and so companies with larger local areas will show a higher number of local switch minutes. The conversion involves multiplying call minutes by a routing factor, estimated according to the type of the call (local, national and international).

Depending on its type, a call can be routed through a number of switches, which in turn are divided into different categories. For the purposes of this analysis, two types of switch are of interest: local and main (also referred to as tandem). Thus, in order to arrive at a suitable measure of call minutes, two routing factors need to be taken into account. The routing factors used in this analysis for TCNZ were supplied directly by TCNZ and are assumed to be robust. The routing factors for the LECs are based on previous work commissioned by Oftel regarding BT's comparative efficiency, and, for the purposes of this analysis, are also assumed to be reasonable. Table A1.9 summarises the routing factors used.

Table A1.9: Routing factors

Type of call	TCNZ	Type of call	LECs[1]
0800 calls	[✂]	Local	[✂]
0900 calls	[✂]	IntraLATA	[✂]
Local–same LCA	[✂]	InterLATA	[✂]
To/from interconnect	[✂]		
To/from international	[✂]		
Toll–different LCA	[✂]		
Internet	[✂]		

Note: [1] Based on Oftel's previous methodology.

To arrive at a 'switch minutes' variable, the analysis would first need to obtain a robust measure of 'call minutes'. The 'call minutes' variable for the LECs is not directly available for local and intraLATA calls, since FCC requires the LECs to report only the number of calls. The ‘call minutes’ variable for these categories is therefore constructed based on estimates of average call duration.

The ‘call minutes’ variable for the LECs constructed for this analysis is arrived at by dividing the number of calls into local, inter-LATA and intra-LATA, and multiplying each call type by an average call-duration figure. This was not necessary for inter-LATA calls since the data collated by the FCC includes inter-LATA billed access minutes. The average call-duration figures used were informed by the aggregate call minutes by type of call measure, published by the FCC and covering the whole of the USA.

Given that the above ‘call minute’ measure is constructed and not provided as collated and audited data, some sensitivity analysis is required to determine the effects of assuming a different set of average call-duration estimates. An alternative set of average call-duration estimates used for sensitivity analysis can be constructed based on the average call durations used for TCNZ. The approach adopted for this analysis first allocates the more disaggregated call categories available for TCNZ to the three LEC categories, and then constructs average call durations based on the proportion of calls found in each category. The average call durations used in the study are detailed in Table A1.10.

Table A1.10: Average call durations by type of call

TCNZ			LECs		
Type of call	**Average duration**	**Allocated to LEC category**	**Type of call**	**Average duration (original)**	**Average duration (alternative)**
0800 calls	[✂]	InterLATA	Local	[✂]	[✂]
0900 calls	[✂]	InterLATA	IntraLATA	[✂]	[✂]
Local (same LCA)	[✂]	Local			
To/from interconnect	[✂]	IntraLATA			
To/from international	[✂]	InterLATA			
Toll (different LCA)	[✂]	IntraLATA			
Internet	[✂]	Local			

Source: TCNZ; OXERA analysis of SOCC.

At this stage, the use by the analysis of the international and inter-LATA call minutes needs clarification. A valid point could be that, since the analysis does not take into account costs incurred for the provision of international call services, and, in the USA, inter-LATA calls are handled by the IXCs, the relevant calls, and therefore call minutes and switch minutes, should not be considered in the analysis. The argument for the inclusion of such calls is that, in each case, their successful completion uses a part of the local network. This usage is reflected in the number of switches assigned to each call type. So, although inter-LATA calls are the most complex to carry from origination to termination, the number of switches assigned to them is the smallest of the three categories. This is because the routing factors used in the analysis do not represent the actual number of switches required to carry a call to its completion, but rather the number of switches used to carry the call in the areas of interest to the analysis—ie, local and national calling areas for TCNZ and LCAs, and LATAs for the LECs.

The analysis considers each category of call minutes separately, but also tests whether the aggregation into a single measure can be regarded as best practice, similar to the treatment applied for the access lines variable. In more detail, the analysis looks at:

- local call minutes;
- other call minutes;
- total call minutes;
- total switched minutes.

A1.3.4Length of sheath

One factor that tends to affect the costs of all network companies is customer density and dispersion, or customer sparsity. One of the most common measures used to approximate customer dispersion is average population density across the geographical area serviced by the network company. However, due to the averaging process involved and the large size of the geographical areas that network companies tend to service, this measure is inappropriate since it does not accurately capture population distribution; a figure of 100 people/km^2 might apply to a company that services a very sparse area and a large customer concentration in an urban conurbation, or equally to a company that services a suburban area. The optimal network structure to adopt in each case is very different.

Comparative-efficiency studies for network companies have overcome this issue lately by using a measure of network length by customer served. In the case of a telecommunications operator, the preferred measure would be length of sheath per access line. This measure could be disaggregated to aerial length of sheath/access line and buried length of sheath/access line. However, this is not possible for the purposes of this analysis since the appropriate data was not available for TCNZ.

Another possible measure to capture customer dispersion could be length of local loop/access line. Larger values of this measure could indicate greater customer dispersion. Therefore, the analysis considers:

- total length of sheath/switched access line;
- total length of sheath/total access line;
- total length of sheath (only considered when an access line measure is also included in the modelling process).

A1.3.5Other environmental factors

The analysis also considers the statistical validity of the length of the local loop and the proportion of business to residential users. The length of the local loop can be viewed as an alternative indicator of customer dispersion, since an operator that serves disperse populations would be expected to have greater values in this indicator. However, there are several technologies available for serving remote communities, some of which use microwave (ie, radio), which could mean that this measure is not appropriate. Nevertheless, the analysis considers it in its variable selection process.

The proportion of business to residential users could also help to explain higher costs incurred for providing more advanced products and billing options to business customers. Therefore, this measure is also considered.

Appendix 2: Results

A2.1 OPEX modelling, including marketing

A2.1.1 Cobb–Douglas cost functions

SFA model, exponential distribution (model A1.e)

```
Stoc. frontier normal/exponential model          Number of obs    =         52
                                                 Wald chi2(2)     =    2863.09
Log likelihood =   16.68877                      Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6139318   .0950898     6.46   0.000     .4275591    .8003044
    lswminor |   .3002742   .0939936     3.19   0.001     .1160502    .4844982
       _cons |  -1.387225   .3615065    -3.84   0.000    -2.095765   -.6786857
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.393139   .4524954    -9.71   0.000    -5.280014   -3.506265
    /lnsig2u |  -3.776792   .5181635    -7.29   0.000    -4.792374    -2.76121
-------------+----------------------------------------------------------------
     sigma_v |   .1111839   .0251551                      .0713608    .1732305
     sigma_u |   .1513143   .0392028                      .0910645    .2514263
      sigma2 |   .0352579   .0098652                      .0159224    .0545934
      lambda |   1.360937   .0572709                      1.248688    1.473186
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.14   Prob>=chibar2 = 0.021
```

SFA model, truncated normal distribution (model A1.t)

```
Stoc. frontier normal/truncated-normal model     Number of obs    =         52
                                                 Wald chi2(2)     =    2767.18
Log likelihood =  16.786098                      Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6176697   .0939249     6.58   0.000     .4335804     .801759
    lswminor |   .2977921   .0923029     3.23   0.001     .1168817    .4787024
       _cons |  -1.415854   .3641971    -3.89   0.000    -2.129667   -.7020405
-------------+----------------------------------------------------------------
         /mu |  -.6702469    2.29092    -0.29   0.770    -5.160368    3.819874
   /lnsigma2 |  -1.738935   1.991234    -0.87   0.383    -5.641681    2.163812
  /ilgtgamma |    2.69037   2.000977     1.34   0.179    -1.231473    6.612213
-------------+----------------------------------------------------------------
      sigma2 |   .1757074   .3498746                      .0035469    8.704251
       gamma |    .936456   .1190705                      .2259236    .9986579
    sigma_u2 |   .1645423    .347793                     -.5171194     .846204
    sigma_v2 |   .0111652   .0061757                     -.0009389    .0232693
------------------------------------------------------------------------------
H0: No inefficiency component:            z =   1.842          Prob>=z = 0.033
```

SFA model, half normal distribution (model A1.h)

```
Stoc. frontier normal/half-normal model          Number of obs    =        52
                                                 Wald chi2(2)     =   2709.62
Log likelihood =  16.639081                      Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |    .619341      .09228     6.71   0.000     .4384754    .8002065
    lswminor |   .2985367    .0902004     3.31   0.001     .1217471    .4753262
       _cons |  -1.488417    .3522796    -4.23   0.000    -2.178872   -.7979613
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.716083    .6680699    -7.06   0.000    -6.025476    -3.40669
    /lnsig2u |  -2.707444    .3979947    -6.80   0.000      -3.4875   -1.927389
-------------+----------------------------------------------------------------
     sigma_v |   .0946053    .0316015                      .0491569    .1820735
     sigma_u |   .2582771    .0513965                      .1748635    .3814809
      sigma2 |   .0756573    .0229645                      .0306477    .1206668
      lambda |   2.730048     .076302                      2.580499    2.879597
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.04   Prob>=chibar2 = 0.022
```

A2.1.2Cobb–Douglas cost functions, using the alternative switch minutes figures

SFA model, exponential distribution (model A2.e)

```
Stoc. frontier normal/exponential model          Number of obs    =        52
                                                 Wald chi2(2)     =   2641.12
Log likelihood =  15.442113                      Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6569538    .0922853     7.12   0.000     .4760779    .8378297
   lswminalt |    .253049    .0892208     2.84   0.005     .0781796    .4279185
       _cons |  -1.211942    .3450466    -3.51   0.000    -1.888221   -.5356632
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.428987    .4429425   -10.00   0.000    -5.297138   -3.560836
    /lnsig2u |  -3.655881    .4811392    -7.60   0.000    -4.598896   -2.712865
-------------+----------------------------------------------------------------
     sigma_v |   .1092088    .0241866                      .0707524    .1685677
     sigma_u |   .1607443    .0386702                      .1003142     .257578
      sigma2 |   .0377653    .0107156                       .016763    .0587676
      lambda |   1.471899     .055169                      1.363769    1.580028
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.95   Prob>=chibar2 = 0.013
```

SFA model, truncated normal distribution (model A2.t)

```
Stoc. frontier normal/truncated-normal model      Number of obs    =        52
                                                  Wald chi2(2)     =   2441.01
Log likelihood =  15.516442                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6573828   .0925127     7.11   0.000     .4760613    .8387044
   lswminalt |   .2536188   .0894339     2.84   0.005     .0783316    .4289059
       _cons |  -1.241188   .3699692    -3.35   0.001    -1.966314   -.5160615
-------------+----------------------------------------------------------------
         /mu |  -1.016227   5.453453    -0.19   0.852     -11.7048    9.672346
   /lnsigma2 |  -1.413416   3.642819    -0.39   0.698    -8.553211    5.726378
  /ilgtgamma |   3.040477   3.604743     0.84   0.399     -4.02469    10.10564
-------------+----------------------------------------------------------------
      sigma2 |   .2433106   .8863366                      .0001929    306.8559
       gamma |   .9543696   .1569803                      .0175553    .9999592
    sigma_u2 |   .2322082   .8837142                      -1.49984    1.964256
    sigma_v2 |   .0111024   .0060519                     -.0007591    .0229638
------------------------------------------------------------------------------
H0: No inefficiency component:           z =    1.920          Prob>=z = 0.027
```

SFA model, half normal distribution (model A2.h)

```
Stoc. frontier normal/half-normal model           Number of obs    =        52
                                                  Wald chi2(2)     =   2433.37
Log likelihood =  15.286111                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6550851   .0928433     7.06   0.000     .4731155    .8370547
   lswminalt |    .258959   .0890031     2.91   0.004     .0845162    .4334018
       _cons |   -1.34034   .3491372    -3.84   0.000    -2.024637   -.6560441
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.740293   .6738583    -7.03   0.000    -6.061031   -3.419555
    /lnsig2u |  -2.617397   .3771956    -6.94   0.000    -3.356687   -1.878107
-------------+----------------------------------------------------------------
     sigma_v |    .093467   .0314918                      .0482907     .180906
     sigma_u |   .2701714   .0509537                       .186683    .3909977
      sigma2 |   .0817287    .024128                      .0344387    .1290187
      lambda |   2.890553   .0753148                      2.742939    3.038168
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.64   Prob>=chibar2 = 0.016
```

A2.1.3Translog cost functions

SFA model, exponential distribution (model A3.e)

```
Stoc. frontier normal/exponential model           Number of obs    =        52
                                                  Wald chi2(5)     =   3555.97
Log likelihood =   23.51247                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   3.945636   1.439127     2.74   0.006     1.124998    6.766274
    lswminor |   -4.27728   1.582514    -2.70   0.007     -7.37895   -1.175609
      lline2 |   1.229405   .5572067     2.21   0.027     .1372994     2.32151
   lswminor2 |    1.28116   .4811724     2.66   0.008     .3380796    2.224241
lline_swmi~r |  -1.218025   .5094978    -2.39   0.017    -2.216622   -.2194273
       _cons |   14.01798   4.248601     3.30   0.001     5.690872    22.34508
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.045076   .4394692    -9.20   0.000     -4.90642   -3.183732
    /lnsig2u |  -5.030784   1.306784    -3.85   0.000    -7.592034   -2.469535
-------------+----------------------------------------------------------------
     sigma_v |   .1323192   .0290751                       .086017    .2035454
     sigma_u |   .0808312   .0528145                      .0224601    .2909024
      sigma2 |   .0240421     .00523                      .0137914    .0342927
      lambda |   .6108805   .0779947                      .4580136    .7637474
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.42   Prob>=chibar2 = 0.259
```

SFA model, truncated normal distribution (model A3.t)

```
Not applicable.
```

SFA model, half normal distribution (model A3.h)

```
Stoc. frontier normal/half-normal model           Number of obs    =        52
                                                  Wald chi2(5)     =   3679.11
Log likelihood =  23.566847                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   3.777118   1.543218     2.45   0.014     .7524663     6.80177
    lswminor |  -4.051704   1.750664    -2.31   0.021    -7.482943   -.6204648
      lline2 |   1.261562   .5541146     2.28   0.023     .1755171    2.347606
   lswminor2 |   1.280637   .4872731     2.63   0.009     .3255992    2.235675
lline_swmi~r |  -1.234167    .509878    -2.42   0.015    -2.233509   -.2348244
       _cons |   13.24858   4.853002     2.73   0.006     3.736874    22.76029
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.362987   .8662773    -5.04   0.000    -6.060859   -2.665115
    /lnsig2u |  -3.466994   1.094073    -3.17   0.002    -5.611338   -1.322651
-------------+----------------------------------------------------------------
     sigma_v |   .1128728   .0488896                      .0482949    .2638018
     sigma_u |   .1766655   .0966425                      .0604663    .5161667
      sigma2 |    .043951   .0244655                     -.0040004    .0919024
      lambda |   1.565173   .1427277                      1.285432    1.844914
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.53   Prob>=chibar2 = 0.234
```

A2.1.4Translog cost functions, using the alternative switch minutes figures

SFA model, exponential distribution (model A4.e)

```
Stoc. frontier normal/exponential model            Number of obs    =         52
                                                   Wald chi2(3)     =    3876.69
Log likelihood =  19.963236                        Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6190678   .0992181     6.24   0.000     .4246039    .8135316
   lswminalt |  -.7540658    .324377    -2.32   0.020    -1.389833   -.1182985
  lswminalt2 |    .060257   .0194514     3.10   0.002     .0221329    .0983811
       _cons |   7.684449   2.856709     2.69   0.007     2.085402     13.2835
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.536676   .5328147    -8.51   0.000    -5.580974   -3.492379
    /lnsig2u |  -3.883314   .5729432    -6.78   0.000    -5.006263   -2.760366
-------------+----------------------------------------------------------------
     sigma_v |    .103484   .0275689                      .0613913    .1744374
     sigma_u |    .143466   .0410989                      .0818284    .2515325
      sigma2 |   .0312914   .0090962                      .0134632    .0491196
      lambda |   1.386359    .062816                      1.263242    1.509476
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.51   Prob>=chibar2 = 0.017
```

SFA model, truncated normal distribution (model A4.t)

```
Stoc. frontier normal/truncated-normal model       Number of obs    =         52
                                                   Wald chi2(3)     =    3897.50
Log likelihood =  19.996658                        Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6230752   .0983504     6.34   0.000      .430312    .8158384
   lswminalt |  -.7434882   .3194666    -2.33   0.020    -1.369631   -.1173452
  lswminalt2 |   .0594147   .0190961     3.11   0.002      .021987    .0968424
       _cons |   7.558874   2.811951     2.69   0.007     2.047551     13.0702
-------------+----------------------------------------------------------------
         /mu |  -1.375151   2.749429    -0.50   0.617    -6.763934    4.013631
   /lnsigma2 |  -1.314717   1.455889    -0.90   0.367    -4.168208    1.538774
  /ilgtgamma |   3.281941   1.504025     2.18   0.029     .3341057    6.229776
-------------+----------------------------------------------------------------
      sigma2 |   .2685504   .3909797                        .01548    4.658876
       gamma |   .9638041   .0524691                       .582758     .998034
    sigma_u2 |     .25883   .3897222                     -.5050115    1.022671
    sigma_v2 |   .0097204   .0059223                     -.0018871     .021328
------------------------------------------------------------------------------
H0: No inefficiency component:            z =   1.786          Prob>=z = 0.037
```

SFA model, half normal distribution (model A4.h)

```
Stoc. frontier normal/half-normal model           Number of obs    =        52
                                                  Wald chi2(3)     =   3436.68
Log likelihood =  19.776251                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopecacc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6204897   .0901924     6.88   0.000     .4437158    .7972636
   lswminalt |  -.7208194    .301082    -2.39   0.017    -1.310929   -.1307095
  lswminalt2 |   .0582092   .0178256     3.27   0.001     .0232717    .0931468
       _cons |   7.337016   2.652267     2.77   0.006     2.138667    12.53536
-------------+----------------------------------------------------------------
    /lnsig2v |  -5.088603   .9890224    -5.15   0.000    -7.027052   -3.150155
    /lnsig2u |   -2.71555   .4314033    -6.29   0.000    -3.561085   -1.870015
-------------+----------------------------------------------------------------
     sigma_v |   .0785279   .0388329                      .0297917    .2069915
     sigma_u |   .2572324   .0554855                      .1685467    .3925829
      sigma2 |   .0723352   .0241571                      .0249881    .1196822
      lambda |   3.275684    .088934                      3.101376    3.449991
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.13   Prob>=chibar2 = 0.021
```

A2.2 OPEX modelling, excluding marketing

A2.2.1Cobb–Douglas cost functions

SFA model, exponential distribution (model B1.e)

```
Stoc. frontier normal/exponential model           Number of obs    =        52
                                                  Wald chi2(2)     =   2292.41
Log likelihood =  12.617591                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lswminor |    .293816    .106605     2.76   0.006     .0848739     .502758
      llines |   .6084076   .1070682     5.68   0.000     .3985578    .8182575
       _cons |  -1.312145   .4075004    -3.22   0.001    -2.110831   -.5134583
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.211283   .4757289    -8.85   0.000    -5.143695   -3.278872
    /lnsig2u |  -3.646044   .5448423    -6.69   0.000    -4.713915   -2.578173
-------------+----------------------------------------------------------------
     sigma_v |   .1217675   .0289642                      .0763943    .1940895
     sigma_u |   .1615368   .0440061                      .0947079    .2755224
      sigma2 |   .0409215   .0114422                      .0184951    .0633478
      lambda |     1.3266   .0656721                      1.197885    1.455315
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 3.42   Prob>=chibar2 = 0.032
```

SFA model, truncated normal distribution (model B1.t)

```
Stoc. frontier normal/truncated-normal model      Number of obs    =        52
                                                  Wald chi2(2)     =   2208.42
Log likelihood =  12.721907                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lswminor |   .2915166   .1023182     2.85   0.004     .0909766    .4920566
      llines |   .6117063   .1033316     5.92   0.000       .40918    .8142326
       _cons |  -1.338058   .4078354    -3.28   0.001    -2.137401   -.5387155
-------------+----------------------------------------------------------------
         /mu |  -.7163231   2.780358    -0.26   0.797    -6.165724    4.733078
   /lnsigma2 |  -1.608196   2.283907    -0.70   0.481    -6.084572     2.86818
 /ilgtgamma  |    2.62009   2.358149     1.11   0.267    -2.001797    7.241977
-------------+----------------------------------------------------------------
      sigma2 |   .2002485    .457349                      .0022777    17.60494
       gamma |   .9321434   .1491579                      .1190143    .9992846
    sigma_u2 |   .1866603    .455408                      -.705923    1.079244
    sigma_v2 |   .0135882   .0072677                     -.0006562    .0278326
------------------------------------------------------------------------------
H0: No inefficiency component:           z =   1.626          Prob>=z = 0.052
```

SFA model, half normal distribution (model B1.h)

```
Stoc. frontier normal/half-normal model           Number of obs    =        52
                                                  Wald chi2(2)     =   2143.39
Log likelihood =  12.551032                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lswminor |   .2975666   .0989045     3.01   0.003     .1037173    .4914159
      llines |   .6079636    .100526     6.05   0.000     .4109362     .804991
       _cons |  -1.422935   .3918016    -3.63   0.000    -2.190852   -.6550174
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.437678   .6107912    -7.27   0.000    -5.634807   -3.240549
    /lnsig2u |  -2.617055   .4151225    -6.30   0.000     -3.43068    -1.80343
-------------+----------------------------------------------------------------
     sigma_v |   .1087353   .0332073                      .0597609    .1978443
     sigma_u |   .2702177   .0560867                      .1799026    .4058731
      sigma2 |    .084841   .0260457                      .0337923    .1358896
      lambda |   2.485097   .0820828                      2.324218    2.645976
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 3.29   Prob>=chibar2 = 0.035
```

A2.2.2Cobb–Douglas cost functions, using the alternative switch minutes figures

SFA model, exponential distribution (model B2.e)

```
Stoc. frontier normal/exponential model           Number of obs    =        52
                                                  Wald chi2(2)     =   2128.68
Log likelihood =   11.31438                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lswminalt |   .2320306   .0966617     2.40   0.016      .042577    .4214841
      llines |   .6662597   .0997395     6.68   0.000     .4707738    .8617456
       _cons |  -1.101144   .3770596    -2.92   0.003    -1.840167   -.3621205
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.277006    .452978    -9.44   0.000    -5.164826   -3.389185
    /lnsig2u |  -3.493638   .4833132    -7.23   0.000    -4.440915   -2.546362
-------------+----------------------------------------------------------------
     sigma_v |   .1178311   .0266875                      .0755914     .183674
     sigma_u |   .1743276   .0421274                      .1085594    .2799398
      sigma2 |   .0442743   .0125857                      .0196068    .0689418
      lambda |    1.47947   .0605488                      1.360796    1.598143
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.38   Prob>=chibar2 = 0.018
```

SFA model, truncated normal distribution (model B2.t)

```
Stoc. frontier normal/truncated-normal model      Number of obs    =        52
                                                  Wald chi2(2)     =   2049.53
Log likelihood =  11.403881                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lswminalt |   .2342525    .095974     2.44   0.015     .0461469     .422358
      llines |   .6648964   .0991857     6.70   0.000      .470496    .8592968
       _cons |  -1.134184   .3861551    -2.94   0.003    -1.891034   -.3773334
-------------+----------------------------------------------------------------
         /mu |  -1.007378   3.162224    -0.32   0.750    -7.205223    5.190466
   /lnsigma2 |   -1.31805    2.07878    -0.63   0.526    -5.392384    2.756283
  /ilgtgamma |   2.972173   2.139882     1.39   0.165    -1.221919    7.166265
-------------+----------------------------------------------------------------
      sigma2 |   .2676566   .5563992                      .0045511    15.74123
       gamma |   .9513011   .0991351                       .227599    .9992284
    sigma_u2 |    .254622   .5551034                     -.8333607    1.342605
    sigma_v2 |   .0130346   .0064848                      .0003246    .0257446
------------------------------------------------------------------------------
H0: No inefficiency component:          z =   1.715          Prob>=z = 0.043
```

SFA model, half normal distribution (model B2.h)

```
Stoc. frontier normal/half-normal model           Number of obs   =        52
                                                  Wald chi2(2)    =   1915.70
Log likelihood =  11.150203                       Prob > chi2     =    0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lswminalt |   .2456715   .0958271     2.56   0.010     .0578538    .4334892
      llines |    .656215   .0995911     6.59   0.000     .4610201      .85141
       _cons |  -1.244399   .3845955    -3.24   0.001    -1.998193   -.4906058
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.490469    .610511    -7.36   0.000    -5.687048   -3.293889
    /lnsig2u |  -2.503798   .3796779    -6.59   0.000    -3.247953   -1.759643
-------------+----------------------------------------------------------------
     sigma_v |   .1059027   .0323274                      .0582201    .1926376
     sigma_u |   .2859613   .0542866                      .1971134     .414857
      sigma2 |   .0929892     .02727                       .039541    .1464375
      lambda |   2.700226   .0787261                      2.545926    2.854527
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.05   Prob>=chibar2 = 0.022
```

A2.1.3Translog cost functions

SFA model, exponential distribution (model B3.e)

```
Stoc. frontier normal/exponential model           Number of obs   =        52
                                                  Wald chi2(5)    =   2951.54
Log likelihood =  19.394237                       Prob > chi2     =    0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   3.967095   1.559034     2.54   0.011     .9114445    7.022745
    lswminor |  -4.378428   1.702784    -2.57   0.010    -7.715823   -1.041032
      lline2 |   1.353258   .6113414     2.21   0.027     .1550504    2.551465
   lswminor2 |   1.375085   .5274247     2.61   0.009     .3413519    2.408819
lline_swmi~r |  -1.323382   .5590999    -2.37   0.018    -2.419198   -.2275663
       _cons |   14.69155   4.507058     3.26   0.001     5.857876    23.52522
-------------+----------------------------------------------------------------
    /lnsig2v |   -3.84685   .4269893    -9.01   0.000    -4.683733   -3.009966
    /lnsig2u |  -5.007034   1.444521    -3.47   0.001    -7.838243   -2.175824
-------------+----------------------------------------------------------------
     sigma_v |   .1461057   .0311928                       .096148    .2220211
     sigma_u |   .0817968   .0590786                      .0198585    .3369192
      sigma2 |   .0280376   .0059585                      .0163592     .039716
      lambda |   .5598468   .0860963                      .3911012    .7285924
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.31   Prob>=chibar2 = 0.288
```

SFA model, truncated normal distribution (model B3.t)

Not applicable.

SFA model, half normal distribution (model B3.h)

```
Stoc. frontier normal/half-normal model           Number of obs    =        52
                                                  Wald chi2(5)     =   2983.30
Log likelihood =  19.397882                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   3.839152   1.658768     2.31   0.021     .5880263    7.090279
    lswminor |  -4.223348   1.843982    -2.29   0.022    -7.837486   -.6092095
      lline2 |   1.368393   .6142817     2.23   0.026     .1644227    2.572363
   lswminor2 |    1.36918    .542277     2.52   0.012     .3063364    2.432023
lline_swmi~r |  -1.327894   .5673778    -2.34   0.019    -2.439934   -.2158534
       _cons |   14.23567   4.925864     2.89   0.004     4.581157    23.89019
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.045674    .750976    -5.39   0.000     -5.51756   -2.573788
    /lnsig2u |   -3.54127   1.329072    -2.66   0.008    -6.146203   -.9363362
-------------+----------------------------------------------------------------
     sigma_v |   .1322797   .0496694                       .063369    .2761271
     sigma_u |   .1702249   .1131206                      .0462774    .6261483
      sigma2 |   .0464744   .0270367                     -.0065165    .0994653
      lambda |   1.286856   .1597861                      .9736812    1.600031
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.32   Prob>=chibar2 = 0.286
```

A2.1.4Translog cost functions, using the alternative switch minutes figures

SFA model, exponential distribution (model B4.e)

```
Stoc. frontier normal/exponential model           Number of obs    =        52
                                                  Wald chi2(3)     =   3344.11
Log likelihood =  16.141047                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6283814   .0993911     6.32   0.000     .4335784    .8231844
   lswminalt |  -.8653913   .3332849    -2.60   0.009    -1.518618    -.212165
  lswminalt2 |   .0654141   .0197823     3.31   0.001     .0266416    .1041866
       _cons |   8.575406   2.916327     2.94   0.003     2.859511     14.2913
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.495893   .5031172    -8.94   0.000    -5.481984   -3.509801
    /lnsig2u |  -3.649905   .5044179    -7.24   0.000    -4.638546   -2.661264
-------------+----------------------------------------------------------------
     sigma_v |   .1056159   .0265686                      .0645063    .1729244
     sigma_u |   .1612253   .0406625                      .0983451    .2643101
      sigma2 |   .0371483   .0108389                      .0159045    .0583921
      lambda |   1.526525   .0601741                      1.408586    1.644464
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.95   Prob>=chibar2 = 0.013
```

SFA model, truncated normal distribution (model B4.t)

```
Stoc. frontier normal/truncated-normal model      Number of obs    =         52
                                                  Wald chi2(3)     =    3292.48
Log likelihood =  16.170329                       Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6276916   .0982348     6.39   0.000      .435155    .8202283
   lswminalt |  -.8583919   .3322286    -2.58   0.010    -1.509548   -.2072357
  lswminalt2 |   .0650392   .0196516     3.31   0.001     .0265229    .1035556
       _cons |   8.512813   2.905089     2.93   0.003     2.818943    14.20668
-------------+----------------------------------------------------------------
         /mu |  -2.108246   11.08229    -0.19   0.849    -23.82914    19.61265
   /lnsigma2 |  -.8640958   4.264335    -0.20   0.839    -9.222039    7.493848
  /ilgtgamma |   3.657265   4.219509     0.87   0.386    -4.612821    11.92735
-------------+----------------------------------------------------------------
      sigma2 |   .4214324   1.797129                      .0000988    1796.953
       gamma |   .9748461   .1034675                      .0098263    .9999934
    sigma_u2 |   .4108317    1.79518                     -3.107657    3.929321
    sigma_v2 |   .0106007   .0059024                     -.0009677    .0221691
------------------------------------------------------------------------------
H0: No inefficiency component:          z =    1.702          Prob>=z = 0.044
```

SFA model, truncated normal distribution (model B4.h)

```
Stoc. frontier normal/half-normal model           Number of obs    =         52
                                                  Wald chi2(3)     =    2707.45
Log likelihood =  15.769141                       Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lopexmrk |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .6081768   .0949837     6.40   0.000     .4220122    .7943415
   lswminalt |  -.8387096   .3269402    -2.57   0.010    -1.479501   -.1979187
  lswminalt2 |   .0649468   .0193516     3.36   0.001     .0270184    .1028752
       _cons |    8.42152   2.882715     2.92   0.003     2.771503    14.07154
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.821734   .7627088    -6.32   0.000    -6.316616   -3.326853
    /lnsig2u |  -2.606691   .3910476    -6.67   0.000    -3.373131   -1.840252
-------------+----------------------------------------------------------------
     sigma_v |   .0897374   .0342218                      .0424976    .1894886
     sigma_u |   .2716215   .0531085                      .1851544    .3984688
      sigma2 |   .0818311   .0249946                      .0328425    .1308196
      lambda |   3.026847   .0806735                       2.86873    3.184965
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.21   Prob>=chibar2 = 0.020
```

A2.3 Total cost modelling, including marketing

A2.3.1Cobb–Douglas cost functions

SFA model, exponential distribution (model C1.e)

```
Stoc. frontier normal/exponential model           Number of obs    =        52
                                                  Wald chi2(3)     =   5831.51
Log likelihood =  32.342874                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
     lcostov |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lswminor |   .3244787   .0727603     4.46   0.000     .1818711    .4670864
      llines |   .5251846   .0658562     7.97   0.000     .3961089    .6542603
    lnsheath |   .0989002   .0342445     2.89   0.004     .0317822    .1660182
       _cons |  -1.133475    .256365    -4.42   0.000    -1.635941   -.6310087
-------------+----------------------------------------------------------------
    /lnsig2v |   -5.27637    .467325   -11.29   0.000    -6.192311    -4.36043
    /lnsig2u |  -4.154304   .4408825    -9.42   0.000    -5.018418   -3.290191
-------------+----------------------------------------------------------------
     sigma_v |   .0714909   .0167047                      .0452227    .1130172
     sigma_u |   .1252865   .0276183                      .0813325    .1929942
      sigma2 |   .0208077   .0061395                      .0087745    .0328408
      lambda |   1.752482    .038545                      1.676935    1.828029
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 7.61   Prob>=chibar2 = 0.003
```

SFA model, truncated normal distribution (model C1.t)

```
Stoc. frontier normal/truncated-normal model      Number of obs    =        49
                                                  Wald chi2(3)     =   6053.67
Log likelihood =  34.759249                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
     lcostov |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lswminor |   .2755546   .0723001     3.81   0.000      .133849    .4172603
      llines |    .557972   .0662226     8.43   0.000     .4281781    .6877659
    lnsheath |   .1178743   .0350169     3.37   0.001     .0492424    .1865063
       _cons |  -.9698248   .2532301    -3.83   0.000    -1.466147    -.473503
-------------+----------------------------------------------------------------
         /mu |  -.4525056   1.166797    -0.39   0.698    -2.739386    1.834375
   /lnsigma2 |   -2.52972   1.468076    -1.72   0.085    -5.407096     .347656
  /ilgtgamma |   2.632514   1.503209     1.75   0.080    -.3137224     5.57875
-------------+----------------------------------------------------------------
      sigma2 |   .0796813   .1169782                      .0044846    1.415745
       gamma |    .932925   .0940647                      .4222064    .9962369
    sigma_u2 |   .0743367    .116127                     -.1532681    .3019415
    sigma_v2 |   .0053446   .0029142                     -.0003671    .0110563
------------------------------------------------------------------------------
H0: No inefficiency component:           z =   1.800          Prob>=z = 0.036
```

SFA model, half normal distribution (model C1.h)

```
Stoc. frontier normal/half-normal model           Number of obs    =         52
                                                  Wald chi2(2)     =          .
Log likelihood =  34.678723                       Prob > chi2      =          .

------------------------------------------------------------------------------
     lcostov |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lswminor |   .2595651   .0555432     4.67   0.000     .1507025    .3684278
      llines |   .5790844    .017302    33.47   0.000     .5451732    .6129957
    lnsheath |   .1188129   .0276415     4.30   0.000     .0646364    .1729893
       _cons |  -1.086059   .4066859    -2.67   0.008    -1.883149   -.2889697
-------------+----------------------------------------------------------------
    /lnsig2v |  -30.86469   97.68653    -0.32   0.752    -222.3268    160.5974
    /lnsig2u |  -2.785376   .1961167   -14.20   0.000    -3.169758   -2.400995
-------------+----------------------------------------------------------------
     sigma_v |   1.99e-07   9.70e-06                      5.28e-49    7.47e+34
     sigma_u |   .2484066   .0243583                      .2049726    .3010445
      sigma2 |   .0617059   .0121016                      .0379873    .0854245
      lambda |    1251255   .0243583                       1251255     1251255
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 12.28  Prob>=chibar2 = 0.000
```

A2.3.2Cobb–Douglas cost functions, using the alternative switch minutes figures

SFA model, exponential distribution (model C2.e)

```
Stoc. frontier normal/exponential model           Number of obs    =         52
                                                  Wald chi2(3)     =    5262.44
Log likelihood =  31.133797                       Prob > chi2      =     0.0000

------------------------------------------------------------------------------
     lcostov |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lswminalt |   .2919782   .0688861     4.24   0.000     .1569639    .4269924
      llines |   .5456243   .0648581     8.41   0.000     .4185049    .6727438
    lnsheath |   .1101525   .0330723     3.33   0.001     .0453321    .1749729
       _cons |  -1.008482   .2474989    -4.07   0.000    -1.493571   -.5233931
-------------+----------------------------------------------------------------
    /lnsig2v |  -5.267616   .4488309   -11.74   0.000    -6.147309   -4.387924
    /lnsig2u |  -4.085494   .4243459    -9.63   0.000    -4.917197   -3.253791
-------------+----------------------------------------------------------------
     sigma_v |   .0718045    .016114                      .0462518    .1114742
     sigma_u |    .129672   .0275129                      .0855548    .1965387
      sigma2 |   .0219707    .006464                      .0093015    .0346399
      lambda |   1.805904   .0374903                      1.732424    1.879383
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 8.98   Prob>=chibar2 = 0.001
```

SFA model, truncated normal distribution (model C2.t)

Stoc. frontier normal/truncated-normal model — Number of obs = 50; Wald chi2(3) = 4.896e+08

Log likelihood = 33.754315 — Prob > chi2 = 0.0000

lcostov	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lswminalt	.2827871	.0556586	5.08	0.000	.1736981	.391876
llines	.5365093	.0242943	22.08	0.000	.4888933	.5841252
lnsheath	.1272553	.0237627	5.36	0.000	.0806813	.1738293
_cons	-.9856716	.3543056	-2.78	0.005	-1.680098	-.2912453
/mu	.0981633	.0428981	2.29	0.022	.0140845	.1822421
/lnsigma2	-3.179824	.0497937	-63.86	0.000	-3.277418	-3.08223
/ilgtgamma	30.16136	1344.393	0.02	0.982	-2604.8	2665.123
sigma2	.041593	.0020711			.0377256	.0458569
gamma	1	1.07e-10			.	1
sigma_u2	.041593	.0020711			.0375338	.0456522
sigma_v2	3.31e-15	4.45e-12			-8.72e-12	8.73e-12

H0: No inefficiency component: z = 2.621 Prob>=z = 0.004

SFA model, half normal distribution (model C2.h)

Stoc. frontier normal/half-normal model — Number of obs = 52; Wald chi2(2) = .

Log likelihood = 33.359197 — Prob > chi2 = .

lcostov	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lswminalt	.2848215	.0667901	4.26	0.000	.1539153	.4157277
llines	.5356212	.029152	18.37	0.000	.4784844	.5927581
lnsheath	.1263868	.0285153	4.43	0.000	.0704979	.1822757
_cons	-.9986225	.4251681	-2.35	0.019	-1.831937	-.1653084
/lnsig2v	-31.15057	95.39663	-0.33	0.744	-218.1245	155.8234
/lnsig2u	-2.734637	.1961155	-13.94	0.000	-3.119017	-2.350258
sigma_v	1.72e-07	8.21e-06			4.31e-48	6.86e+33
sigma_u	.2547892	.0249841			.2102394	.3087791
sigma2	.0649175	.0127313			.0399646	.0898705
lambda	1480609	.024984			1480609	1480609

Likelihood-ratio test of sigma_u=0: chibar2(01) = 13.43 Prob>=chibar2 = 0.000

A2.3.3Translog cost functions

SFA model, exponential distribution (model C3.e)

```
Stoc. frontier normal/exponential model           Number of obs    =        52
                                                  Wald chi2(3)     =   7738.59
Log likelihood =  34.383818                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
     lcostov |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .4593101    .063771     7.20   0.000     .3343212     .584299
    lswminor |  -.5030015   .2620614    -1.92   0.055    -1.016632    .0106295
   lswminor2 |   .0553727   .0149163     3.71   0.000     .0261373    .0846081
       _cons |   6.882149   2.260352     3.04   0.002      2.45194    11.31236
-------------+----------------------------------------------------------------
    /lnsig2v |  -5.261313   .5931522    -8.87   0.000     -6.42387   -4.098756
    /lnsig2u |  -4.293749   .5359248    -8.01   0.000    -5.344142   -3.243356
-------------+----------------------------------------------------------------
     sigma_v |   .0720311   .0213627                      .0402786     .128815
     sigma_u |   .1168488   .0313111                      .0691089    .1975669
      sigma2 |   .0188421   .0057709                      .0075313     .030153
      lambda |   1.622198   .0481585                      1.527809    1.716587
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 3.93   Prob>=chibar2 = 0.024
```

SFA model, truncated normal distribution (model C3.t)

```
Not applicable.
```

SFA model, half normal distribution (model C3.h)

```
Stoc. frontier normal/half-normal model           Number of obs    =        52
                                                  Wald chi2(3)     =   9019.80
Log likelihood =  35.154427                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
     lcostov |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .4494839   .0617665     7.28   0.000     .3284238    .5705439
    lswminor |  -.4647877   .2044759    -2.27   0.023    -.8655531   -.0640224
   lswminor2 |   .0541041   .0117103     4.62   0.000     .0311524    .0770558
       _cons |   6.502353    1.81183     3.59   0.000     2.951233    10.05347
-------------+----------------------------------------------------------------
    /lnsig2v |  -6.380897   1.137616    -5.61   0.000    -8.610583   -4.151211
    /lnsig2u |  -3.119489   .3112167   -10.02   0.000    -3.729462   -2.509515
-------------+----------------------------------------------------------------
     sigma_v |   .0411534   .0234084                      .0134969    .1254804
     sigma_u |   .2101898   .0327073                      .1549379     .285145
      sigma2 |   .0458734   .0126123                      .0211538    .0705929
      lambda |    5.10747   .0509063                      5.007696    5.207245
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 5.47   Prob>=chibar2 = 0.010
```

A2.3.4Translog cost functions, using the alternative switch minutes figures

SFA model, exponential distribution (model C4.e)

```
Stoc. frontier normal/exponential model          Number of obs   =         52
                                                 Wald chi2(3)    =    7870.02
Log likelihood =  34.118887                      Prob > chi2     =     0.0000

------------------------------------------------------------------------------
     lcostov |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |    .469277   .0607939     7.72   0.000     .3501231    .5884309
   lswminalt |   -.669715   .2367569    -2.83   0.005     -1.13375     -.20568
  lswminalt2 |   .0640319   .0137755     4.65   0.000     .0370323    .0910314
       _cons |   8.291283   2.077272     3.99   0.000     4.219905    12.36266
-------------+----------------------------------------------------------------
    /lnsig2v |  -5.325934   .4917012   -10.83   0.000    -6.289651   -4.362218
    /lnsig2u |  -4.233364   .4600666    -9.20   0.000    -5.135078    -3.33165
-------------+----------------------------------------------------------------
     sigma_v |    .069741   .0171459                      .0430744    .1129163
     sigma_u |   .1204306    .027703                      .0767241    .1890347
      sigma2 |   .0193673   .0057788                      .0080411    .0306936
      lambda |   1.726826    .039534                      1.649341    1.804312
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 7.94   Prob>=chibar2 = 0.002
```

SFA model, truncated normal distribution (model C4.t)

```
Stoc. frontier normal/truncated-normal model     Number of obs   =         52
                                                 Wald chi2(3)    =   11574.72
Log likelihood =  34.381722                      Prob > chi2     =     0.0000

------------------------------------------------------------------------------
     lcostov |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .4516657   .0563272     8.02   0.000     .3412665     .562065
   lswminalt |  -.5965388   .1796494    -3.32   0.001    -.9486451   -.2444325
  lswminalt2 |   .0609864    .010433     5.85   0.000     .0405381    .0814348
       _cons |   7.682127   1.597038     4.81   0.000      4.55199    10.81226
-------------+----------------------------------------------------------------
         /mu |   .0153262   .2123261     0.07   0.942    -.4008253    .4314776
   /lnsigma2 |  -3.058782   .6898073    -4.43   0.000     -4.41078   -1.706785
  /ilgtgamma |   3.560954   1.070542     3.33   0.001      1.46273    5.659179
-------------+----------------------------------------------------------------
      sigma2 |   .0469448   .0323829                      .0121457    .1814482
       gamma |   .9723732   .0287586                      .8119499    .9965267
    sigma_u2 |   .0456479   .0319773                     -.0170265    .1083222
    sigma_v2 |   .0012969    .001339                     -.0013275    .0039214
------------------------------------------------------------------------------
H0: No inefficiency component:           z =   2.526          Prob>=z = 0.006
```

SFA model, half normal distribution (model C4.h)

Stoc. frontier normal/half-normal model — Number of obs = 52; Wald chi2(3) = 11517.11; Prob > chi2 = 0.0000

Log likelihood = 34.379361

lcostov	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
llines	.4522031	.0554448	8.16	0.000	.3435333	.5608729
lswminalt	-.595036	.1788308	-3.33	0.001	-.9455379	-.244534
lswminalt2	.0608711	.0103126	5.90	0.000	.0406587	.0810835
_cons	7.667253	1.584814	4.84	0.000	4.561073	10.77343
/lnsig2v	-6.614366	.9313988	-7.10	0.000	-8.439874	-4.788858
/lnsig2u	-3.040783	.2580693	-11.78	0.000	-3.54659	-2.534977
sigma_v	.0366192	.0170535			.0146996	.0912248
sigma_u	.2186263	.0282104			.1697727	.2815379
sigma2	.0491384	.0118328			.0259465	.0723303
lambda	5.970266	.038915			5.893994	6.046538

Likelihood-ratio test of sigma_u=0: chibar2(01) = 8.46 Prob>=chibar2 = 0.002

A2.4 Total cost modelling, excluding marketing

A2.4.1Cobb–Douglas cost functions

SFA model, exponential distribution (model D1.e)

Stoc. frontier normal/exponential model — Number of obs = 52; Wald chi2(2) = 3985.02; Prob > chi2 = 0.0000

Log likelihood = 26.360343

lcostalt	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
lswminor	.4498829	.0688378	6.54	0.000	.3149632	.5848025
llines	.461016	.069606	6.62	0.000	.3245908	.5974412
_cons	-1.365647	.2991025	-4.57	0.000	-1.951877	-.7794165
/lnsig2v	-5.05279	.5135036	-9.84	0.000	-6.059238	-4.046341
/lnsig2u	-3.91842	.4599183	-8.52	0.000	-4.819843	-3.016997
sigma_v	.0799467	.0205265			.048334	.1322355
sigma_u	.1409697	.0324173			.0898223	.221242
sigma2	.0262639	.0078706			.0108378	.0416901
lambda	1.763296	.0467978			1.671574	1.855018

Likelihood-ratio test of sigma_u=0: chibar2(01) = 7.69 Prob>=chibar2 = 0.003

SFA model, truncated normal distribution (model D1.t)

```
Stoc. frontier normal/truncated-normal model      Number of obs    =        52
                                                  Wald chi2(2)     =   3656.79
Log likelihood =  26.497446                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lcostalt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lswminor |   .4534802   .0684724     6.62   0.000     .3192767    .5876836
      llines |   .4592495   .0693168     6.63   0.000      .323391     .595108
       _cons |  -1.421543   .3201578    -4.44   0.000    -2.049041   -.7940456
-------------+----------------------------------------------------------------
         /mu |  -.4821396   1.789447    -0.27   0.788    -3.989391    3.025111
   /lnsigma2 |  -2.058014   1.994967    -1.03   0.302    -5.968077    1.852049
  /ilgtgamma |   3.174059   1.723914     1.84   0.066    -.2047504    6.552868
-------------+----------------------------------------------------------------
      sigma2 |   .1277074   .2547719                      .0025592    6.372863
       gamma |   .9598463    .066442                      .4489905     .998576
    sigma_u2 |   .1225794   .2523521                     -.3720216    .6171805
    sigma_v2 |   .0051279   .0041609                     -.0030274    .0132832
------------------------------------------------------------------------------
H0: No inefficiency component:          z =   2.577          Prob>=z = 0.005
```

SFA model, half normal distribution (model D1.h)

```
Stoc. frontier normal/half-normal model           Number of obs    =        52
                                                  Wald chi2(2)     =   3576.99
Log likelihood =  26.373361                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lcostalt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lswminor |    .459698   .0658569     6.98   0.000     .3306208    .5887753
      llines |   .4538761   .0688547     6.59   0.000     .3189234    .5888287
       _cons |   -1.48392   .2854606    -5.20   0.000    -2.043413   -.9244276
-------------+----------------------------------------------------------------
    /lnsig2v |  -5.787007   1.070798    -5.40   0.000    -7.885733   -3.688281
    /lnsig2u |  -2.833373   .3383078    -8.38   0.000    -3.496444   -2.170302
-------------+----------------------------------------------------------------
     sigma_v |   .0553818   .0296514                      .0193925    .1581612
     sigma_u |   .2425162   .0410226                      .1740832    .3378507
      sigma2 |   .0618813   .0178369                      .0269216     .096841
      lambda |   4.378984   .0648843                      4.251813    4.506155
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 7.71   Prob>=chibar2 = 0.003
```

A2.4.2Cobb–Douglas cost functions, using the alternative switch minutes figures

SFA model, exponential distribution (model D2.e)

```
Stoc. frontier normal/exponential model           Number of obs    =         52
                                                  Wald chi2(2)     =    3335.29
Log likelihood =   23.34072                       Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lcostalt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lswminalt |   .3985361   .0702337     5.67   0.000     .2608806    .5361916
      llines |   .5082579   .0723406     7.03   0.000     .3664729     .650043
       _cons |   -1.18379   .3060916    -3.87   0.000    -1.783719   -.5838614
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.905013   .4763964   -10.30   0.000    -5.838733   -3.971293
    /lnsig2u |  -3.826762    .449463    -8.51   0.000    -4.707693   -2.945831
-------------+----------------------------------------------------------------
     sigma_v |   .0860776   .0205035                      .0539679    .1372918
     sigma_u |   .1475806    .033166                       .095003    .2292561
      sigma2 |   .0291894   .0085898                      .0123536    .0460251
      lambda |   1.714507   .0468981                      1.622588    1.806426
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 6.44   Prob>=chibar2 = 0.006
```

SFA model, truncated normal distribution (model D2.t)

```
Stoc. frontier normal/truncated-normal model      Number of obs    =         52
                                                  Wald chi2(2)     =    3152.90
Log likelihood =  23.542573                       Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lcostalt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lswminalt |   .4070946   .0714431     5.70   0.000     .2670688    .5471205
      llines |   .5010691   .0740812     6.76   0.000     .3558726    .6462657
       _cons |  -1.250336   .3136555    -3.99   0.000     -1.86509   -.6355831
-------------+----------------------------------------------------------------
         /mu |  -.3593366   .4182634    -0.86   0.390    -1.179118    .4604445
   /lnsigma2 |  -2.151496   .4758992    -4.52   0.000    -3.084242   -1.218751
  /ilgtgamma |   2.887584   .7463569     3.87   0.000     1.424751    4.350416
-------------+----------------------------------------------------------------
      sigma2 |     .11631   .0553518                      .0457647    .2955991
       gamma |   .9472292   .0373074                      .8060821    .9872629
    sigma_u2 |   .1101722   .0548724                      .0026243    .2177201
    sigma_v2 |   .0061378   .0037168                      -.001147    .0134226
------------------------------------------------------------------------------
H0: No inefficiency component:           z =   2.240          Prob>=z = 0.013
```

SFA model, half normal distribution (model D2.h)

```
Stoc. frontier normal/half-normal model          Number of obs   =         52
                                                 Wald chi2(2)    =    2953.62
Log likelihood =  23.410864                      Prob > chi2     =     0.0000

------------------------------------------------------------------------------
    lcostalt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lswminalt |   .4162184   .0714449     5.83   0.000      .276189    .5562479
      llines |   .4925744   .0753153     6.54   0.000     .3449592    .6401897
       _cons |  -1.311075   .3084167    -4.25   0.000     -1.91556   -.7065891
-------------+----------------------------------------------------------------
    /lnsig2v |  -5.359063   .7716131    -6.95   0.000    -6.871397   -3.846729
    /lnsig2u |  -2.810086   .3360808    -8.36   0.000    -3.468792   -2.151379
-------------+----------------------------------------------------------------
     sigma_v |   .0685953   .0264645                      .0322029    .1461145
     sigma_u |   .2453565   .0412298                      .1765068    .3410625
      sigma2 |   .0649052    .018212                      .0292102    .1006001
      lambda |   3.576871   .0612339                      3.456855    3.696888
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 6.58   Prob>=chibar2 = 0.005
```

A2.4.3Translog cost functions

SFA model, exponential distribution (model D3.e)

```
Stoc. frontier normal/exponential model          Number of obs   =         49
                                                 Wald chi2(5)    =    6322.74
Log likelihood =  35.555444                      Prob > chi2     =     0.0000

------------------------------------------------------------------------------
    lcostalt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   2.412805   1.113637     2.17   0.030      .230116    4.595494
    lswminor |  -3.337004   1.231497    -2.71   0.007    -5.750694   -.9233145
      lline2 |   .9430424   .4148564     2.27   0.023     .1299388    1.756146
   lswminor2 |   .9657351   .3636123     2.66   0.008     .2530682    1.678402
lline_swmi~r |  -.8968923   .3805819    -2.36   0.018    -1.642819   -.1509654
       _cons |   17.09006   3.494723     4.89   0.000     10.24053    23.93959
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.934722   .6664677    -7.40   0.000    -6.240975   -3.628469
    /lnsig2u |  -4.874623   .9482554    -5.14   0.000     -6.73317   -3.016077
-------------+----------------------------------------------------------------
     sigma_v |   .0848084    .028261                      .0441357    .1629626
     sigma_u |   .0873955   .0414366                      .0345073    .2213437
      sigma2 |   .0148304   .0042157                      .0065678    .0230931
      lambda |   1.030505    .066788                      .8996034    1.161407
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.77   Prob>=chibar2 = 0.190
```

SFA model, truncated normal distribution (model D3.t)

Not applicable.

SFA model, half normal distribution (model D3.h)

```
Stoc. frontier normal/half-normal model          Number of obs    =         52
                                                  Wald chi2(5)     =  1.350e+10
Log likelihood =  40.421873                       Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lcostalt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   2.347447   .0047242   496.90   0.000     2.338188    2.356706
    lswminor |  -2.291845   .0046989  -487.74   0.000    -2.301055   -2.282635
      lline2 |   .8155887   .0012298   663.19   0.000     .8131784     .817999
   lswminor2 |    .816325   .0009475   861.55   0.000     .8144679    .8181821
lline_swmi~r |  -.7885745    .001031  -764.90   0.000    -.7905951   -.7865539
       _cons |   8.504816   .0062143  1368.60   0.000     8.492636    8.516995
-------------+----------------------------------------------------------------
    /lnsig2v |  -31.33877   74.07147    -0.42   0.672    -176.5162    113.8387
    /lnsig2u |  -3.006255    .196118   -15.33   0.000    -3.390639    -2.62187
-------------+----------------------------------------------------------------
     sigma_v |   1.57e-07   5.80e-06                      4.68e-39    5.25e+24
     sigma_u |   .2224335   .0218116                      .1835406    .2695678
      sigma2 |   .0494766   .0097033                      .0304586    .0684947
      lambda |    1420125   .0218116                       1420125     1420125
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 14.95  Prob>=chibar2 = 0.000
```

A2.4.4Translog cost functions, using the alternative switch minutes figures

SFA model, exponential distribution (model D4.e)

```
Stoc. frontier normal/exponential model          Number of obs    =         52
                                                  Wald chi2(3)     =    7793.80
Log likelihood =  32.762314                       Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lcostalt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .4549071   .0598254     7.60   0.000     .3376516    .5721626
   lswminalt |  -.7093561   .2317244    -3.06   0.002    -1.163528   -.2551846
  lswminalt2 |    .066686   .0134431     4.96   0.000     .0403379     .093034
       _cons |   8.708032   2.034428     4.28   0.000     4.720626    12.69544
-------------+----------------------------------------------------------------
    /lnsig2v |  -5.443267   .6157114    -8.84   0.000    -6.650039   -4.236495
    /lnsig2u |  -4.069206   .4749054    -8.57   0.000    -5.000004   -3.138409
-------------+----------------------------------------------------------------
     sigma_v |   .0657672   .0202468                      .0359718    .1202422
     sigma_u |   .1307324   .0310427                      .0820848    .2082108
      sigma2 |   .0214163   .0068232                      .0080431    .0347895
      lambda |   1.987804   .0462781                        1.8971    2.078507
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 8.98   Prob>=chibar2 = 0.001
```

SFA model, truncated normal distribution (model D4.t)

```
Stoc. frontier normal/truncated-normal model      Number of obs    =        52
                                                  Wald chi2(3)     =  17059.74
Log likelihood =  34.148215                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lcostalt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .4313231   .0494902     8.72   0.000      .334324    .5283221
   lswminalt |  -.6482815   .1412102    -4.59   0.000    -.9250483   -.3715146
  lswminalt2 |   .0646259   .0088419     7.31   0.000      .047296    .0819558
       _cons |    8.24331   1.356359     6.08   0.000     5.584895    10.90172
-------------+----------------------------------------------------------------
         /mu |   .0275597   .1718865     0.16   0.873    -.3093317    .3644511
   /lnsigma2 |  -2.989192   .6029088    -4.96   0.000    -4.170871   -1.807513
  /ilgtgamma |   4.681879   1.234204     3.79   0.000     2.262884    7.100873
-------------+----------------------------------------------------------------
      sigma2 |   .0503281   .0303432                      .0154388    .1640617
       gamma |   .9908234   .0112219                      .9057561    .9991763
    sigma_u2 |   .0498662    .030198                     -.0093207    .1090532
    sigma_v2 |   .0004618   .0005702                     -.0006557    .0015794
------------------------------------------------------------------------------
H0: No inefficiency component:           z =   2.597          Prob>=z = 0.005
```

SFA model, half normal distribution (model D4.h)

```
Stoc. frontier normal/half-normal model           Number of obs    =        52
                                                  Wald chi2(3)     =  17558.83
Log likelihood =  34.137337                       Prob > chi2      =    0.0000

------------------------------------------------------------------------------
    lcostalt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      llines |   .4318395   .0483954     8.92   0.000     .3369863    .5266928
   lswminalt |  -.6452302   .1384497    -4.66   0.000    -.9165867   -.3738737
  lswminalt2 |   .0644173   .0086096     7.48   0.000     .0475428    .0812918
       _cons |   8.216281   1.324385     6.20   0.000     5.620533    10.81203
-------------+----------------------------------------------------------------
    /lnsig2v |  -7.611943   1.143468    -6.66   0.000    -9.853099   -5.370787
    /lnsig2u |  -2.911602    .224854   -12.95   0.000    -3.352307   -2.470896
-------------+----------------------------------------------------------------
     sigma_v |   .0222376    .012714                      .0072515    .0681943
     sigma_u |   .2332135   .0262195                      .1870922    .2907045
      sigma2 |   .0548831   .0120715                      .0312233    .0785428
      lambda |   10.48736    .032397                      10.42386    10.55086
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 11.73  Prob>=chibar2 = 0.000
```