COMMERCIAL IN CONFIDENCE

FINAL REPORT

A review of the Commerce Commission's constant price revenue model

Prepared for
Wellington Electricity

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THE CENTRE FOR INTERNATIONAL ECONOMICS
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Executive summary

This report undertakes an empirical and theoretical review of the New Zealand Commerce Commission's constant price revenue model (CPRM). Following this, it then considers whether there are alternative low cost forecasting approaches that could improve on the model used by the Commission. Our key findings are presented below.

Measuring Constant Price Revenue

Any model for considering constant price revenue growth should use as its basis an accurate measure of this. We construct such a measure using a weighting of quantity of electricity supplied across different customer groups and the number of residential ICPs, weighted according to their revenue share for each electricity distribution business (EDB).

- Our analysis shows that from 2010 to 2012, constant price revenue has declined for most EDBs (table 1). This is in contrast to conclusions that could be drawn from the data used in the Commission's empirical modelling.
- The average decline under the CIE's measure is 0.9 per cent per year from 2010 to 2012, compared to the Commission's measure of deflated revenue, which shows a 1.7 per cent increase per year on average.

1 Index of quantity for each EDB

EDB	Growth 2008 to 2012	Growth 2010 to 2012
	Per cent/ year	Per cent/ year
Alpine	0.5	-2.7
Aurora	0.1	-0.5
Centralines	0.0	-0.1
Eastland	0.0	-0.3
Ashburton	-0.3	-5.8
Invercargill	0.5	-0.9
Horizon Energy	0.5	-1.7
Nelson Electricity	-0.3	-0.5
Network Tasman	0.6	0.7
Orion		
OtagoNet	0.4	-1.1
Powerco	0.2	0.5
The Lines Company	-1.1	-0.5

EDB	Growth 2008 to 2012	Growth 2010 to 2012
	Per cent/ year	Per cent/ year
Top Energy	0.2	-0.4
Unison	-0.2	-1.3
Vector	na	0.3
Wellington Electricity	na	-1.3
Total	**0.3**	**-0.3**
Average	**0.1**	**-0.9**

Note: The total includes all EDBs, even where data is not available for all years, and reflects the weights of the EDBs as it is calculated by adding up electricity volumes and connection points across all EDBs. The average is a straight average across the EDBs for which data is reported in the table.
Source: The CIE.

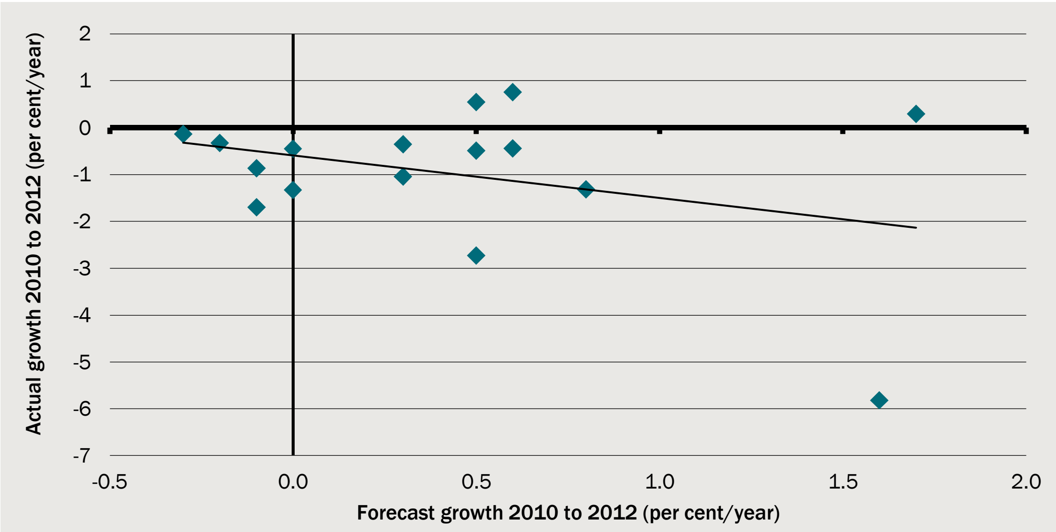
Accuracy of Constant Price Revenue forecasts

We have assessed the accuracy of previous forecasts of constant price revenue developed by the Commission over the period 2010 to 2012. The methodology used by the Commission has had little ability to predict actual outcomes. Over the period 2010 to 2012, the approach has:

- over-forecast constant price revenue growth for most EDBs. From 2010 to 2012, the average forecast error was 1.4 per cent per year; and
- generated forecasts of growth that are not positively correlated with actual growth across EDBs (chart 2).

The lack of predictive ability of the model does not reflect the underlying drivers of GDP and population growth, with the average error reducing from 1.4 per cent per year to 1.3 per cent per year if actual GDP and population growth rates are used in the CPRM.

2 Assessment of the performance of the CPRM using the CIE's measure



Data source: The CIE.

From this analysis, we conclude that the CPRM has little predictive ability. We also find that in-sample fitting of particular parts of the model, such as the impact of GDP on constant price revenue can explain very little of the variation in outcomes. These findings are not surprising, as the CPRM is a relatively simple model that is aiming to be low cost.

An alternative low cost forecasting methodology

The appropriate test of the CPRM is whether there is a low cost alternative that can produce forecasts that are less biased and more accurate and therefore would lead to EDBs recovering close to their efficient costs.

We find that while there are better statistical models that can be estimated (better in that they improve on the in-sample fit relative to the Commission's models) these are not sufficiently reliable to be used as a basis for forecasts for regulatory purposes.

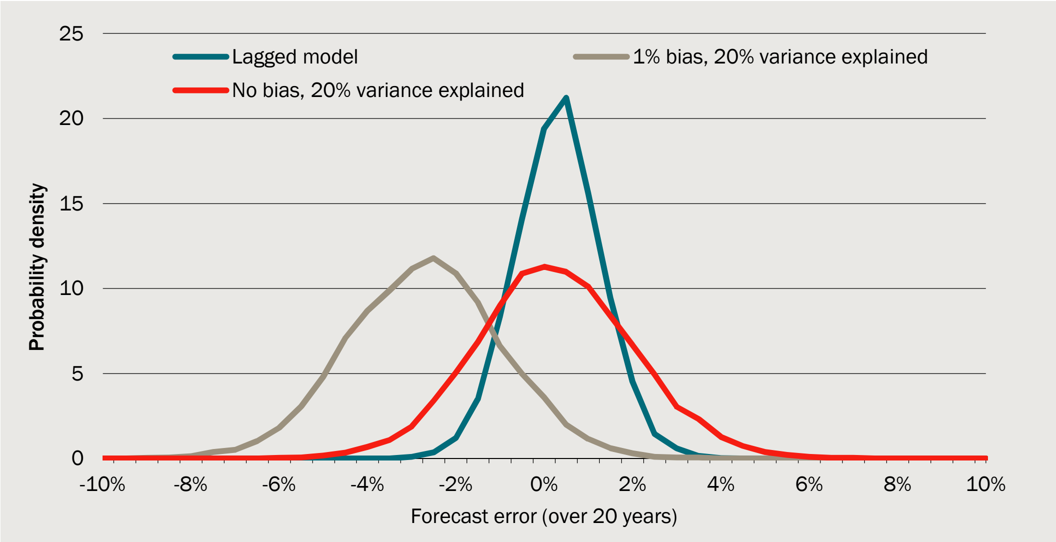
- Unless further effort is put into improving forecast accuracy and bias, the forecast process will lead to EDBs taking on substantial forecast risk over which they have no control.
- Even with substantial effort the ability to reduce forecast errors using forecasts made for a future regulatory period is likely to be limited under a low-cost approach. Only a customised bottom-up forecast has the potential to materially reduce forecasting error.

Given that this effort is not low cost, we have investigated whether an alternative model not based on a statistical forecasting approach could lead to an outcome where EDBs would recover their efficient costs. We find that a model that would achieve these objectives is to use historical constant price revenue growth (such as over the previous regulatory period) as the projection of future constant price revenue growth.

- Testing of such a model finds that this would lead to an EDB receiving (and customers paying) revenue close to efficient costs over a 20 year period. This model is guaranteed to be unbiased and forecast errors over a 20 year period are between plus and minus two percent (see chart 3).
- This is a better outcome than any empirical specification that has any level of bias — whether this is bias for a particular EDB or bias across all EDBs. For example, chart 3 shows the cumulated errors over 20 years for a model that has a 1 per cent constant price revenue growth bias.
- This simple model also leads to a better outcome that an *unbiased* empirical specification, as long as this specification could explain less than half of observed revenue growth variation. Our empirical testing found no model close to this — chart 3 shows the cumulated errors over 20 years for a model that can explain 20 per cent of the variation, which is likely to be a more realistic if still somewhat optimistic assessment of the performance of a simple empirical model.

The simple model that we recommend — using lagged constant price revenue growth — performs well because it balances out bias and errors over a longer time period than a single regulatory period. This would provide greater certainty to EDBs that they could recover their costs and to customers that they would not pay more than the efficient costs of providing services.

3 Lagged revenue versus unbiased and biased statistical models



Data source: The CIE.

1 *Our approach to reviewing the performance of the constant price revenue growth model*

This chapter outlines the context and framework used for our theoretical and empirical review of the constant price revenue model (CPRM) and the methods used to measure its forecast performance.

Context

This report provides a theoretical and empirical review of the New Zealand Commerce Commission's (the Commission) constant price revenue model (CPRM) over the current regulatory period.

The electricity distribution businesses (EDBs) across New Zealand are subject to Part 4 of the Commerce Act 1986, which specifies that default/customized price paths apply to all EDBs that are not defined as consumer-owned. An EDB can apply for a customized price path, if it believes an alternative customized path is needed to satisfy its particular circumstances.

There are a number of components that make up a price-quality path over a regulatory period, including:

- a maximum starting price that a business is allowed to charge
- an annual rate at which all businesses' starting prices can increase
  - this is expressed in the form of 'CPI-X'. This means prices are restricted from increasing each year by more than the rate of inflation, less an adjustment to account for productivity improvements.
- a minimum service quality standard that a business must meet.

The Commission has adopted a model for calculating starting prices for the current regulatory period, based on current and projected profitability of each distributor. This involves forecasting each distributor's costs and constant price revenue over the regulatory period, and then adopting a starting price to achieve a desired level of profitability.

Forecasts of constant revenue growth are a particularly important input into this process and can significantly affect EDBs future profitability. For example, if constant revenue growth is over-predicted for an EDB, then this will tend to lead to the starting price and the default price path over the regulatory period being lower than it would otherwise be. On the other hand, under-estimating future revenue will have the opposite effect. These forecast errors have clear implications for EDBs revenue and profit.

Review framework

At its most basic, a forecasting model is a set of dependent or left hand side variables representing demand (a vector of customer numbers, demand or growth in demand, etc) and its relationship to a set of explanatory or right hand side variables.

Mathematically, this can be represented as follows.[1]

$$\widetilde{D}_t = B.\widetilde{X}_{t/t-1} + \widetilde{\varepsilon}_t$$

Where

$\widetilde{D}_t$ is a Nx1 vector capturing N different types of demand at time t.

$\widetilde{X}_{t/t-1}$ is a Mx1 vector of explanatory variables (such as population level, income level). It can be for variables of the current period (t) or past periods (such as t-1)

B is a NxM matrix of coefficients (such as the response of customer numbers to a higher population)

$\widetilde{\varepsilon}_t$ is a Nx1 vector of error terms in the forecasts

The Commission's model fits into this framework.

Forecasting therefore requires two components.

1 Establishing values for the B that link drivers to demand. For example, one component of B might be that a 1 per cent increase in price reduces electricity use by 0.3 per cent.
2 Projecting forward the drivers of demand, X. For example, if price is a driver then a forecast of price is required.

It has to be recognised in any forecasting exercise that there will be forecast errors. Forecast errors can arise because:

- of errors in the data used to build the model;
- of errors in the estimation technique and model used;
- the relationship between a driver of demand (such as price) and demand may change over time; and
- of errors in forecasts of drivers (such as population growth).[2]

In the case of the Commission's model (or any forecasting model), errors may arise in the following respects.

- The model structure is imperfect. This could include:
  – the model omits some drivers of revenue, such as weather, income, sectoral GDP or electricity prices; or
  – the functional form of the forecasting model is incorrect

1 Note that this sets out the deterministic components only. We would also model the variation of the error term for daily distribution points for the purposes of forecasting peak demand.

2 See Hendry, D. and M. Clements 2001, "Economic forecasting: some lessons from recent research", *Economic modelling*, vol. 20(2), pages 301-329, March for a full taxonomy of forecast errors.

- The relationship between drivers and what is being forecast are incorrectly estimated or have changed over time. This could be the case for:
  - the relationship between GDP and commercial and industrial revenue (either for Wellington or more broadly)
  - the relationship between electricity use and residential revenue, which the Commerce Commission assumed is 1:1. This may not be the case because of residential tariff structures
  - the relationship between population and residential users, which may change because of changes in household size
- The drivers were incorrectly estimated, such as population growth or the change in real GDP

Of these issues, the first two are the most problematic. The latter is less directly relevant in determining forecast bias issues because incorrect forecasts of drivers over the *previous period* may or may not imply that this is likely in the *forecast period*. However, this can give an indication as to the magnitude of likely forecast errors.

This report seeks to disentangle these possible sources of error in the case of electricity revenue in New Zealand. Before doing this we first examine issues around data.

Measurement of forecast performance

Two key measures of forecast performance are forecast bias and the magnitude of forecast errors, as set out below. Forecast bias is particularly problematic for revenue forecasts as this could mean an EDB can systematically over or under-recover their efficient costs.

Forecast bias

Forecast bias can be thought of in terms of both bias over time and bias across jurisdictions. Forecast bias over time for a particular jurisdiction would be consistent with the model systematically over or under predicting future values of constant revenue growth or GDP growth. Forecast bias across jurisdictions would be consistent with the model systematically over or under predicting constant price revenue or GDP growth of jurisdictions with similar characteristics such as location or industry composition.

Magnitude of forecast errors

The magnitude of forecast errors is a measure of the accuracy of a model. The magnitude of forecast errors is assessed in this report using the mean absolute percentage error (MAPE) and the root mean square error (RMSE). Both measures are defined below:

$$RMSE = \sqrt{\sum_{t=1}^{n}\left(\frac{A_t - F_t}{n}\right)}$$

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \times 100$$

Where:

A_t is actual data

F_t is forecast data

n is the number of observations.

The mean absolute percentage error is the preferred method as it accounts for the scale of the variable being forecast. However, the root mean squared error is a more practical metric in instances when the forecast variables range includes zero. These measures allow the modelling errors of the CPRM to be compared across jurisdictions and potentially compared to the modelling errors recorded by other agencies.

2 Measuring constant price revenue

The variable that is being forecast by the Commission is constant price revenue. Constant price revenue is not directly observable historically. This leads to significant complications for any analysis used to determine a forecasting model.

Appropriate definition of constant price revenue

Constant price revenue seeks to measure the change in revenue that an EDB would achieve over time if prices did not change. An alternative way of expressing this is as weighted average demand, where the weights reflect the shares of revenue. For example, suppose 'demand' is the amount of electricity sold to residential, commercial and industrial customers (Q_t^r, Q_t^c and Q_t^i where r, c and i are for the customer classes and t is time) and the number of connection points (N_t). Then in this case, weighted average demand can be calculated as follows.

$$WQ_t = \sum_{j=(r,c,i)} \frac{Q_t^j}{Q_0^j} \cdot \frac{R^j}{R} + \sum_{j=(r,c,i)} \frac{N_t^j}{N_0^j} \cdot \frac{RN^j}{R}$$

Where Q is quantity of electricity supplied, N is number of connections, R is total revenue, R^j is the revenue from volume components for customer class j and RN^j is the revenue from fixed charges for customer class j. Revenue shares are calculated as an average across tariff classes.

With one simplification, this definition of constant price revenue growth can be estimated from 2008 to 2012 for each EDB. The one simplification is that RN is measured only for residential (which is defined as small and medium connections given the data available). For larger customers, all revenue is assumed to be from volumes of electricity sold.[3]

The calculation of an index of quantity using this method is set out in table 2.1.

3 Note that customer classes available from the datasets is small, medium, large and 5 largest connections. Constant price revenue could also be calculated using data on billed quantities and revenue from the Electricity Distributors Information Disclosures August 2013.

2.1 Index of quantity for each EDB

EDB	2008	2009	2010	2011	2012	Growth 2008 to 2012	Growth 2010 to 2012
	Index	Index	Index	Index	Index	Per cent/ year	Per cent/ year
Alpine	100.0	105.3	107.9	106.6	102.1	0.5	-2.7
Aurora	100.0	99.7	101.4	98.1	100.5	0.1	-0.5
Centralines	100.0	102.9	100.5	105.2	100.2	0.0	-0.1
Eastland	100.0	99.2	100.5	100.2	99.8	0.0	-0.3
Ashburton	100.0	110.4	111.5	115.3	98.9	-0.3	-5.8
Invercargill	100.0	101.3	103.8	103.7	102.0	0.5	-0.9
Horizon Energy	100.0	99.6	105.8	102.1	102.2	0.5	-1.7
Nelson Electricity	100.0	99.6	99.8	97.5	98.8	-0.3	-0.5
Network Tasman	100.0	99.0	101.1	100.9	102.6	0.6	0.7
Orion							
OtagoNet	100.0	108.1	103.9	101.8	101.7	0.4	-1.1
Powerco	100.0	100.3	99.6	99.2	100.6	0.2	0.5
The Lines Company	100.0	94.8	96.5	96.7	95.6	-1.1	-0.5
Top Energy	100.0	99.6	101.6	99.5	100.9	0.2	-0.4
Unison	100.0	98.9	101.8	101.9	99.1	-0.2	-1.3
Vector	100.0	76.4	77.5	76.7	77.9		0.3
Wellington Electricity		100.0	150.9	147.0	146.9		-1.3
Total	**100.0**	**97.1**	**101.8**	**100.9**	**101.2**	**0.3**	**-0.3**
Average						**0.1**	**-0.9**

Note: The total includes all EDBs, even where data is not available for all years, and reflects the weights of the EDBs as it is calculated by adding up electricity volumes and connection points across all EDBs. The average is a straight average across the EDBs for which data is reported in the table.
Source: The CIE.

Commission definition of constant price revenue

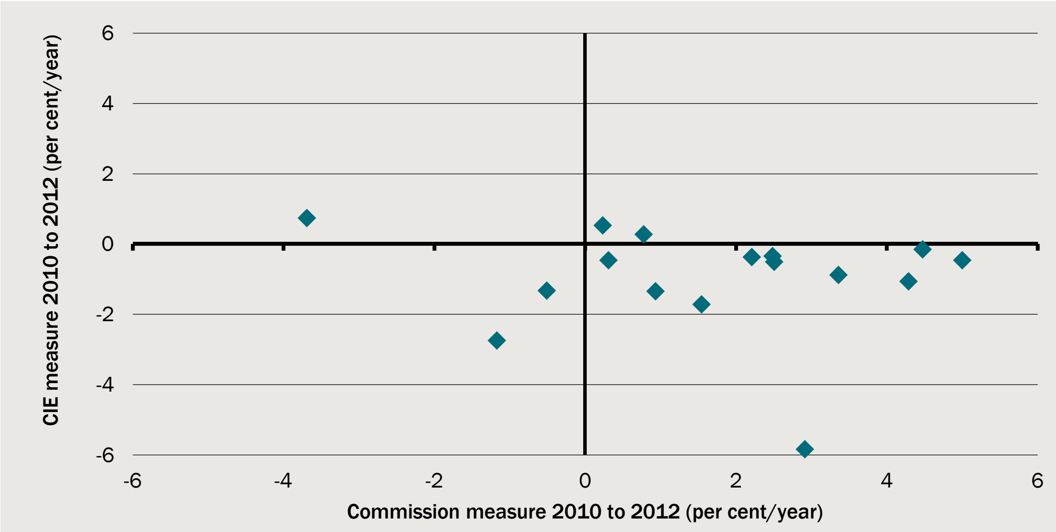
The Commission has defined constant price revenue as the change in revenue that is due to changes in electricity usage by residential, commercial and industrial users. The Commission has noted previously that it does not have any information on actual constant price revenue (or alternatively it is an 'unobserved variable'), and has relied on approximations in previous modelling exercises.[4]

The approximation used in modelling by the Commission is actual revenue deflated by the CPI. This is a conceptually correct measure if EDB's prices have increased by CPI over the period covered. This has not been the case.

[4] Commerce Commission, *Resetting the 2010-15 Default Price-Quality Paths for 16 Electricity Distributors,* 2012.

A comparison of the CIE's and Commission's measures of constant price revenue is shown in chart 2.2. Under the Commission's method, constant price revenue has generally increased from 2010 to 2012. Under the CIE's measure, constant price revenue has generally decreased from 2010 to 2012. The average decline under the CIE's measure is 0.9 per cent per year over the two year period, compared to the Commission data which shows a 1.7 per cent increase per year. These are very different views of the outcomes for EDBs over the historical period.

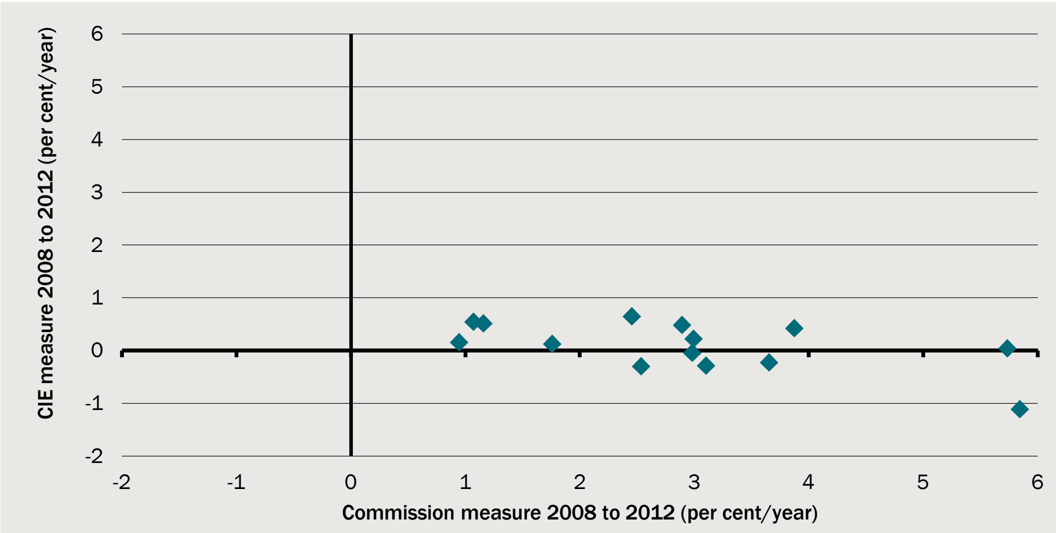
2.2 Comparison of measures of constant price revenue 2010 to 2012



Data source: Commerce Commission New Zealand, The CIE.

The differences between the methods are larger if a longer period is used, because of substantial price changes for some EDBs in earlier years (chart 2.3).

2.3 Comparison of measures of constant price revenue 2008 to 2012



Note: Vector and Wellington Electricity are not included.
Data source: Commerce Commission New Zealand, The CIE.

Data errors are a significant issue in developing a forecasting model, particularly in this case because the errors are so large and impact on the variable being forecast (rather than 'driver' variables. These errors undermine the analysis conducted by the Commission to develop its forecasts.

The reason for the significant differences between the measures of constant price revenue growth is price changes. In particular:

- changes in actual prices have often been inconsistent with the default price path specified, and
- deflating revenue by the CPI will not fully account for the impact of the changes in allowed annual price growth over the 2010 regulatory year and the 2011 regulatory year.[5]

Table 2.4 below illustrates that there have been a number of price breaches over the current regulatory period as well as in the 2010 regulatory year. In fact, eight of the EDBs that are currently on a default price path were in breach of their price path during the 2010 regulatory year.

2.4 Price path breaches 2010 to 2012

	2010	2011	2012	2013
Alpine Energy				
Aurora Energy				
Centralines	Breach			
Eastland Network	Breach			
Electricity Ashburton				
Electricity Invercargill				
Horizon Energy	Breach		Breach	
Nelson Electricity	Breach			
Network Tasman				
OtagoNet	Breach			
Powerco				
The Lines Company	Breach			
Top Energy	Breach			
Unison				
Vector				
Wellington	Breach		Breach	

Source: The CIE, Commerce Commission New Zealand

5 For example, the prices of some EDBs were allowed to grow by (CPI - 2 per cent) during the 2010 regulatory year.

While there were a number of reasons for the breaches seen between 2010 and 2013, the main motives were:

- a number of EDBs perceived that the rate of return on their network assets was below what the Commission was likely to consider fair
- the starting prices for the 2011-15 regulatory period were based on the *actual prices* at the end of the 2010 regulatory year, and
- new regulations that were introduced at the beginning of the 2010-15 regulatory period significantly increase the possibility of EDBs being fined for price breaches.
- forecasting errors of pass through and recoverable costs and mid-year price restructures

For example, The Lines Company noted in it 2010 Annual Report that:

> Prices from 1 April 2010, under the latest Commerce Commission decision will only be able to increase in totality at the rate of inflation. It was recognised at the time of the 2009 increase that the increase still left a significant gap between the return we were earning on our network assets and the return that the Commission was likely to consider fair.
>
> The decision was therefore made to increase prices before the 1 April 2010 to bring our return closer to fair return. Prices were increased on 29 March 2010.
>
> As a result of that increase and growth in demand over the last year, we would expect our network revenue to grow by 10 per cent over the 2011 year.
>
> The two price increases have breached the old Commission pricing threshold. If the Commission believes that as a result our returns will be excessive then it has the ability to require us to lower our prices. Any breach from 1 April 2010 will however incur the possibility of significant fines. We consider that it was important that our prices as at March 31 2010 were ones that were sustained.

Price breaches from 2004 to 2009 are shown in table 2.5.

As a result of historic price changes, deflating line change revenue by CPI has significantly overestimated the growth in real constant price revenue. This can be seen in the difference between the CIE's index of weighted quantity versus the Commission's measure of deflated revenue.

A better reading of historical outcomes for EDBs would suggest more pessimistic historical outcomes than shown in the Commission's data. This would then presumably mean more pessimistic forecasts.

2.5 Price breaches 2004 to 2009

	2004	2005	2006	2007	2008	2009
Alpine Energy	Breach		Breach			Breach
Aurora Energy	Breach					
Centralines						Breach
Eastland Network						Breach
Electricity Ashburton						Breach
Electricity Invercargill	Breach					
Horizon Energy						Breach
Nelson Electricity			Breach			Breach
Network Tasman			Breach			
Orion NZ	Breach	Breach				
OtagoNet						Breach
Powerco	Breach					
The Lines Company						
Top Energy	Breach		Breach	Breach		Breach
Unison		Breach	Breach			
Vector	Breach			Breach		
Wellington						

Source: Commerce Commission New Zealand, *Regulation of Electricity Lines Businesses Targeted Control Regime, Reasons for Not Declaring Control of the Electricity Distribution Businesses,* various years:

3 Performance of New Zealand electricity revenue forecasts

In 2012, the Commission retrospectively estimated default price-quality paths for each EDB over the current regulatory period (1 April 2010 to 31 March 2015) using new input methodologies. As part of this process, the Commission produced forecasts of constant price revenue growth using the CRPM over the current regulatory period. As a result, the performance of the CPRM can in theory be preliminarily assessed by comparing model forecasts to measures of constant price revenue recorded so far over the regulatory period.

The measurement of the performance of New Zealand electricity revenue forecasts is complicated by the issues above about what actual performance has been. This chapter shows forecast performance under 3 methods.

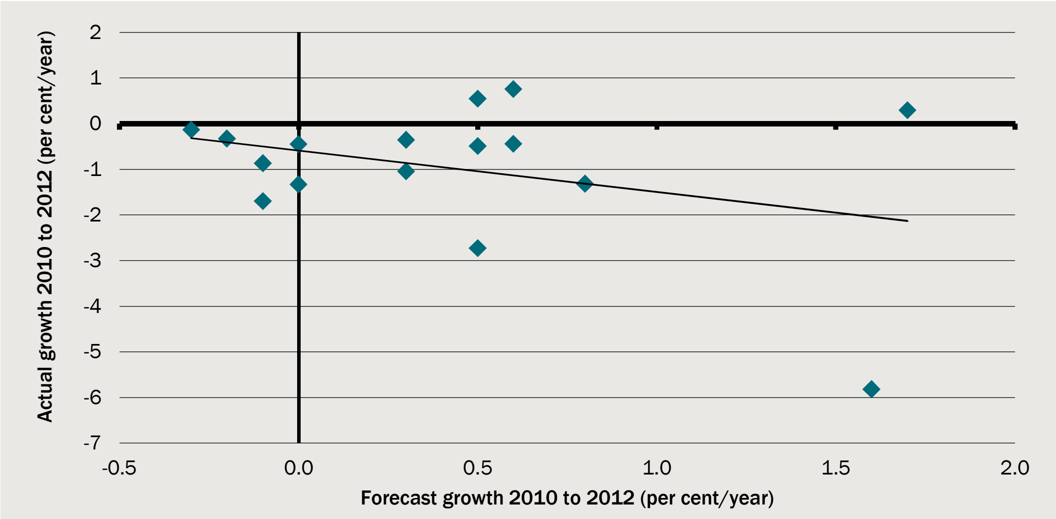
1. The CIE's preferred measure of weighted quantity
2. The Commission's measure of constant price revenue
3. The quantity of electricity supplied

Performance using the CIE's preferred measure

The performance of the CPRM is assessed against CIE's measure of weighted quantity from 2010 to 2012 (chart 3.1 and table 3.2).

- The model has systematically over-predicted constant price revenue growth over this period. The amount across all EDBs has been over 1 per cent revenue growth per year. (This has a cumulative impact on EDBs.)
- Across EDBs, there is no indication that those EDBs which had a higher forecast growth had a higher actual growth (in fact these measures are negatively correlated). This suggests the model has little real forecasting power.

3.1 Assessment of the performance of the CPRM using the CIE's measure



Data source: Commerce Commission New Zealand, The CIE

3.2 Assessment of the performance of the CPRM using the CIE's measure

	CPRM forecasts Change from 2010 to 2012	The CIE's weighted quantity measure Change from 2010 to 2012	
	Change	Change	Forecast error
	Per cent/year	Per cent/year	Percentage pt/year
North Island			
Powerco	0.5	0.5	0.0
Eastland	-0.2	-0.3	-0.1
Centralines	-0.3	-0.1	0.2
Top Energy	0.3	-0.4	-0.7
Unison	0.0	-1.3	-1.3
Lines Company	0.0	-0.5	-0.5
Horizon Energy	-0.1	-1.7	-1.6
Vector	1.7	0.3	-1.4
Wellington	0.8	-1.3	-2.1
South Island			
Network Tasman	0.6	0.7	0.1
Alpine Energy	0.5	-2.7	-3.2
Ashburton	1.6	-5.8	-7.4
Aurora Energy	0.6	-0.5	-1.1
Nelson Electricity	0.5	-0.5	-1.0
OtagoNet	0.3	-1.1	-1.4
Invercargill	-0.1	-0.9	-0.8
Average	**0.4**	**-1.0**	**-1.4**
Total	**0.9**	**-0.3**	**-1.2**

Sources: The CIE, Commerce Commission New Zealand.

Other approximations of constant price revenue

In previous modelling exercises, the Commission has measured constant price revenue by deflating line charge revenue with the CPI. This measure may be a useful approximation for constant price revenue over the current regulatory period, as EDBs have been constrained from increasing their prices by the rate of CPI growth.

Table 3.3 compares the cumulative growth in line charge revenue deflated by CPI across EDBs from 2010 to 2013 to CRPM forecasts of cumulative growth over the same period. This shows a different result to the calculations above, with actual revenue growth being higher than forecast using the Commission's method. Using electricity supplied gives a similar conclusion to that using the CIE's preferred measure.

3.3 Assessment of the performance of the CPRM using alternative measures

	CPRM forecasts Change from 2010 to 2013	Electricity supplied measure Change from 2010 to 2013		Deflated revenue measure Change from 2010 to 2013	
		Change	Forecast error	Change	Forecast error
	Per cent/ year	Per cent/ year	Percentage point/year	Per cent/ year	Percentage point/year
North Island					
Powerco	0.5	1.6	1.1	0.8	0.3
Eastland	-0.2	0.6	0.8	2.0	2.2
Centralines	-0.3	-0.3	0.0	6.2	6.5
Top Energy	0.3	0.6	0.3	7.7	7.4
Unison	0.0	-0.3	-0.3	1.8	1.8
Lines Company	0.0	-0.9	-0.8	7.4	7.4
Horizon Energy	-0.1	-1.0	-0.9	1.0	1.1
Vector	1.7	0.3	-1.4	1.4	-0.3
Wellington	0.8	-1.3	-2.1	-1.8	-2.6
South Island					
Network Tasman	0.6	1.1	0.5	2.4	1.8
Alpine Energy	0.5	-1.0	-1.6	2.2	1.7
Ashburton	1.6	1.0	-0.6	5.3	3.7
Aurora Energy	0.6	-0.6	-1.3	0.0	-0.7
Nelson Electricity	0.5	-0.8	-1.3	3.5	3.0
OtagoNet	0.3	-2.4	-2.7	5.0	4.7
Invercargill	-0.1	-3.0	-2.9	2.1	2.2
Average	**0.4**	**-0.4**	**-0.8**	**2.9**	**2.5**

Sources: The CIE, Commerce Commission New Zealand.

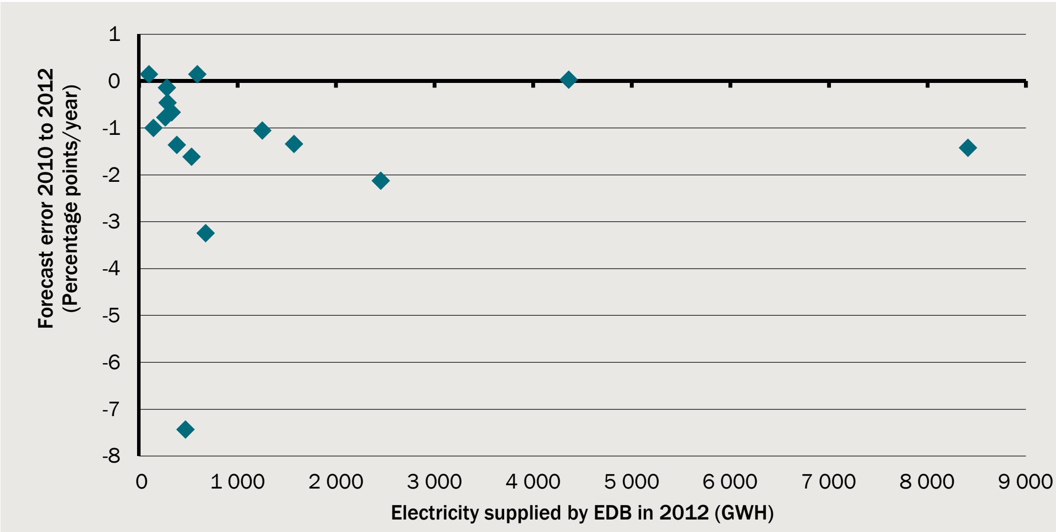
Factors affecting CPRM forecast accuracy

The errors in forecasting may be systematic — for example if they reflect the size of EDBs or the composition of the economy for particular EDBs. We find no strong evidence that could explain the relative forecast errors across different EDBs, as set out below.

Size of EDBs

The size of an EDB as measured by the amount of electricity supplied in the 2011 regulatory year was found to have little correlation with the cumulative forecast error (using the electricity supply measure) of growth from 2010 to 2012 That is, the method is not systematically better for smaller or larger EDBs (see chart 3.4).

3.4 Cumulative forecast error from 2010 to 2012 and size of EDB

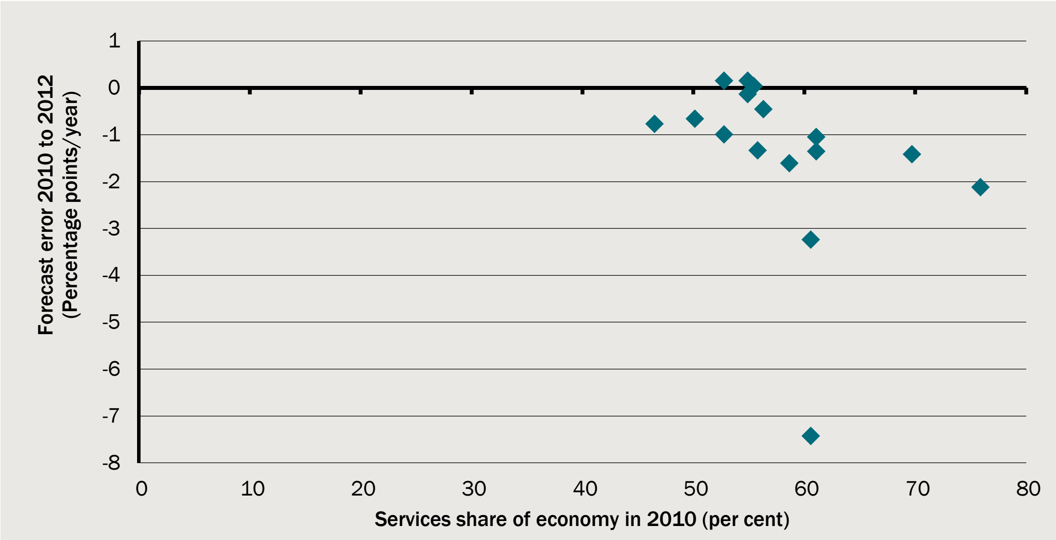


Data source: The CIE, Commerce Commission New Zealand.

Industry composition

The constant price revenue for regions that have a higher services share has tended to be overestimated to a somewhat larger degree than for other regions (chart 3.5). This may reflect the performance of different regions of NZ rather than a specific issue with the GDP relationship used by the Commission. For example, the share of GDP growth from 2010 to 2012 that was from services does not have any relationship to the forecast error.

3.5 Cumulative forecast error 2010 to 2012 and services share of GDP



Data source: The CIE, Commerce Commission New Zealand.

Impact of forecasting errors

Forecasts of constant price revenue growth directly affect the maximum allowable revenue (MAR) that EDBs are able to earn in each year of the regulatory period. To calculate MAR, the Commission firstly estimates the following costs in present value terms over the regulatory period:[6]

- the return on capital, net of any revaluations of the Regulatory Asset Base (RAB)
- the return of capital, to allow recovery of depreciation
- operating expenditure (excluding pass through costs and recoverable costs), and
- tax costs

An expected revenue path is then estimated in order to determine the revenue that EDBs would require to earn in each year to recover the present value of these costs. The growth of this revenue path is a function of:

- forecast growth in the CPI
- forecasts of constant price revenue growth, and
- an industry specific productivity parameter.

In the event that the CPRM model over-predicts constant price revenue growth over the regulatory period, this would tend to lead to lower levels of MAR than what is required to recover EDBs expected costs over the regulatory period. On the other hand, under-estimates of constant price revenue growth over the regulatory period would tend to lead to higher levels of MAR than what may be required to recover EDBs expected costs.

[6] Commerce Commission New Zealand, *Resetting the 2010-15 Default Price-Quality Paths for 16 Electricity Distributors*, 2012.

On average, over the period 2010 to 2012, forecasts over-estimated quantity growth by 2.5 per cent. This is equivalent to a 2.5 per cent reduction in revenue. This equates to a larger impact on return on capital. For example, if return on capital comprises 25 per cent of costs, then a 2.5 per cent reduction in revenue is equivalent to a 10 per cent reduction in return on capital.[7]

Key points

- **The CPRM has over-forecast quantity growth by >1 per cent per year across all EDBs over the period 2010 to 2012.**
- **There is no relationship between the actual constant price revenue growth that occurred from 2010 to 2012 and the forecast across EDBs. That is, the model does not appear to have any power in differentiating outcomes across EDBs.**
- **The Commission's measure of CPR suggests that its model is under-forecasting quantity growth, which is at odds with the CIE's measure of constant price revenue. This would suggest that there has not been an accurate assessment of the model's historical performance.**
- **The impact of forecasting errors on EDBs is substantial. The average bias in forecasts from 2010 to 2012 would reduce revenue by 2.5 per cent by the second year and equate to a larger impact on return on capital.**

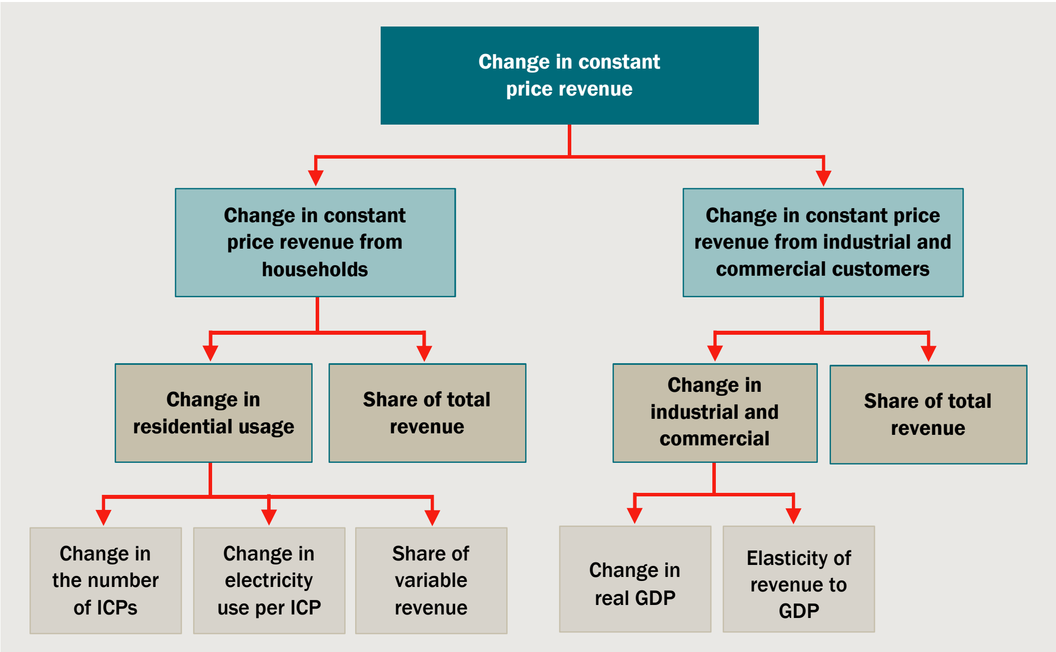
7 Note that this assumes that changes in quantity do not change costs.

4 Review of the modelling framework used by Commission

The constant price revenue model

Chart 4.2 below provides a schematic overview of the constant price revenue model. The Commission has essentially adopted a mathematical identity and used approximations for the components of the identity. This methodology is distinct from the use of time series techniques that forecast growth based on historical outcomes or the development of a causal or economic model that would aim to identify the key underlying drivers of revenue growth.

4.1 Schematic overview of constant price revenue model



Source: The CIE.

Table 4.2 illustrates the key approximations and assumptions used in the CPRM. A detailed review of these assumptions is conducted later in this report.

4.2 Key approximations and assumptions used in the CPRM

Parameter	Approximation/assumption
Change in the number of residential ICPs	Change in the population
Change in residential electricity use	Equals the change in population, with zero change in electricity use per person
Change in industrial and commercial usage	Real GDP multiplied by estimated elasticity of constant price revenue to GDP

Source: The CIE.

Implicit within the model are a number of less direct assumptions, such as:

- a given percentage change in electricity use per residential user is associated with the same change in volume-based revenue per residential user:
  - this may not be the case if there are price structures such as peak and off-peak, block pricing etc;
- industrial and commercial usage revenue can be considered jointly:
  - that is, the amount of revenue from value added in each production sector is equal and responds in the same way to an increase in GDP;
- industrial and commercial usage revenue is invariant to the tariff structures of each business or the customer composition of each business;
- electricity prices and weather are not important drivers of electricity use, either residential or commercial;
- there is no feedback from a Commission decision to change starting point prices to demand;
- the most recent year's revenue is an appropriate starting point for forecasts.

Benchmarking the Constant Price Revenue Growth Model

There are a number of examples of other approaches used to forecast demand for electricity, either for revenue or planning purposes. Below we set out the approach used by the Australian Energy Market operator (AEMO) and the principles used by the Australian Energy Regulator. We then consider how the modelling framework used by the Commission aligns to these benchmarks.

AEMO

AEMO prepares forecasts of electricity use for each Australian state.[8] This comprises models for:

- residential and commercial customers;
- industrial customers; and
- post-model adjustments for solar PV and energy efficiency.

AEMO forecasts are prepared annually and project for a period of 10 years.

8 See AEMO 2014, National Electricity Forecasting Report, June and supporting documents.

The forecasts for residential and commercial customers are of most relevance for EDB revenue. These forecasts comprise a long run relationship and short run component to move models back to long-term relationships. They are estimated on the basis of per capita energy demand. The factors that they find are key drivers of per capita electricity demand are:

- weather — modelled through heating degree days and cooling degree days;
- income/GDP — higher income leads to higher electricity use;
- electricity prices — higher prices reduces electricity use; and
- seasonality — models are estimated using quarterly data.

Australian Energy Regulator

In reviewing demand forecasts for electricity and gas distributors, the AER has considered that, to the extent feasible, to meet best practice, forecasts should:[9]

- be accurate and unbiased
- incorporate key drivers, including weather
- incorporate policy impacts
- be transparent and repeatable
- include model validation and testing.

Commission forecasts against AEMO and AER forecasting

Both AEMO and the AER would consider that forecasts should consider key drivers. In the context of electricity demand this would include weather, electricity prices, income and policy factors such as weather and policy.

The Commission's forecasting approach would not meet the benchmarks of these other approaches because, while it allows for population and GDP, it does not allow for other key drivers, particularly weather, prices and policy.

The Commission is seeking a low cost approach and the forecasting approaches used by AEMO and for regulated businesses in Australia may not meet the definition of low cost. Given this, we consider the performance of the models used against much simpler models than those used in the Australian context.

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9 These have been articulated by ACIL Tasman, *Victorian electricity distribution price review: review of electricity sales and customer number forecasts*, prepared for the Australian Energy Regulator, April 2010.

4.3 Benchmarking the CPRM

Variables	Model	Variables	Frequency of review
AEMO annual energy forecasts for Australian states	Integrated dynamic model ▪ Includes a long-run relationship between energy consumption, real income and real electricity prices ▪ Separate adjustments for energy efficiency, solar on top of this model	▪ Population ▪ Weather ▪ Real electricity prices ▪ Real income/GDP ▪ Seasonal factors	Annual
Australian energy regulator	Does not specify – developed by distributors	▪ Key drivers should be included, such as weather and policy	Prior to regulatory decision for period of 4-5 years
Commission Constant price energy forecasts by region	Mathematical identity ▪ Includes an estimate of the elasticity of constant price revenue to GDP growth.	▪ Population ▪ Real GDP	5 years

Source: The CIE.

Focus of CPRM forecasts

In constructing a model of the constant price revenue earned by EDBs it is important to understand the proportion of revenue sourced from households and commercial and industrial users. If only a small minority of income is sourced from commercial and industrial users, then errors in forecasting electricity use of this segment of the population will have a relatively small impact on the overall forecast error.

The methodology employed by the Commission has various levels of resources devoted to different parts of the forecasting task. In particular, it has explored forecasting approaches for commercial and industrial revenue in greater detail than for residential revenue.

Across the EDBs that are currently on a default price path, income generated from residential users represents just under 63 per cent of total income generated (see table 4.4 below). The proportion of income sourced from households varies from 27 per cent, in Electricity Ashburton, to 87 per cent in Top Energy.

While the Commission should develop robust forecasts for all inputs, the substantial share of revenue from residential users suggests that a greater focus should be placed on forecasting residual usage and connections compared to commercial and industrial usage and connections.

4.4 Sources of revenue across EDBs 2011

EDB	Residential	Commercial & industrial
	Per cent	Per cent
Alpine Energy	74.8	25.2
Aurora Energy	57.9	42.1
Centralines	56.5	43.5
Eastland Network	54.4	45.6
Electricity Ashburton	26.5	73.5
Electricity Invercargill	54.7	45.3
Horizon Energy	50.6	49.4
Nelson Electricity	46.1	53.9
Network Tasman	48.4	51.6
Otago Joint Venture	44.2	55.8
Powerco	76.3	23.7
The Lines Company	68.9	31.1
Top Energy	87.2	12.8
Unison	56.6	43.4
Vector	57.7	42.3
Wellington Electricity	74.9	25.1
Total	**62.8**	**37.2**

Sources: The CIE, Commerce Commission New Zealand, Section 53ZD Information Request, April 2012.

Key points

- **The main drivers of electricity demand used by other forecasts are prices, population, income and weather. These are all factors over which an EDB has no control**
- **The Commission's model does not account for key drivers of electricity quantities used by other forecasters, such as weather and electricity prices**
- **The Commission's resources have been focused on commercial and industrial revenue. While the techniques to forecast this are less obvious and this may be the reasons for this forecasting focus, this sector accounts for a lower share of revenue than residential customers for EDBs**

5 Review of forecasts of drivers

The New Zealand economy has been hit by three significant shocks over the current regulatory period. These include:

- the 2010-11 Canterbury earthquakes[10]
- the sharp decline in commodity prices during 2012[11,12]
- the 2012-13 drought[13,14]

A relevant question is to what extent this could explain the poor performance of the CPRM. We find that while GDP projections and population projections have been inaccurate, this explains very little of the errors generated by the CPRM.

Real GDP forecasts

Review of data source

The CPRM uses regional GDP forecasts sourced from New Zealand Institute of Economic Research (NZIER), which estimates regional GDP by apportioning national level industry activity to each region, mainly using labour market and population shares. For example, if Auckland has 40 per cent of finance, insurance, property and business service jobs, then 40 per cent of national activity in the industry is apportioned to Auckland. [15] While this apportionment is the commonly accepted approach to regional GDP estimates in the absence of official estimates, it does have its limitations. For example, a regional specific shock, such as the 2010-11 earthquake, that impacts national GDP is likely to be misallocated at a regional level.

The NZIER regional GDP estimates are used by the Commission to allocate GDP forecasts to each EDB's network area based on the following rules.

- if an EDB network area is within a NZIER region, the regional GDP forecasts are attributed to the EDB.

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10 Reserve Bank of New Zealand, *The economic impact of the Canterbury earthquakes*, 2012.

11 Reserve Bank of New Zealand, *Exchange rate and commodity price pass-through in New Zealand,* 2014

12 Inaccurate forecasts of revenue growth for Electricity Ashburton and Alpine Energy may also reflect their proximity to the 2010-11 earthquakes.

13 National Institute of Water and Atmospheric Research (NIWA), *The 2012-13 drought: an assessment and historical perspective*, June 2013.

14 Treasury, *Budget Economic and Fiscal Update 2013.*

15 NZIER, Regional Economies Estimates, forecasts and issues, 2012

- if an EDB network crosses regional boundaries, the GDP growth attributed to an EDB is a weighted average of activity in each region, where the weights depend on the share of the network area located in each region.

Review of forecast accuracy

Table 5.1 compares the cumulative growth in real GDP growth over 1 April 2010 to March 31 2013 to forecasts of cumulative growth over the same period. Overall, the regional forecasts have been broadly consistent with the growth observed in the New Zealand economy in the first three years of the regulatory period. In addition, there has been a more even distribution of forecast errors across EDBs compared to forecasts of constant revenue growth, with GDP growth stronger than forecast in close to 60 per cent of the EDBs.

However, the forecasts have misallocated growth across the North and South Islands. In particular, the regions that have grown less than expected have generally been located in the South Island. This is in part likely to reflect the 2011-12 earthquakes.

5.1 Preliminary assessment of the accuracy of GDP forecasts

	Real GDP 2011 to 2013	GDP forecasts 2011 to 2013	Forecast error
	Cumulative per cent change	Cumulative per cent change	Cumulative percentage points
North Island			
Centralines	5.6	0.3	5.4
Eastland Network	5.6	0.3	5.4
Unison	6.7	1.2	5.5
Horizon Energy	7.9	2.7	5.2
The Lines Company	7.1	3.9	3.1
Nelson Electricity	6.2	4.3	1.8
Powerco	5.4	3.8	1.6
Top Energy	3.5	1.8	1.7
Vector	9.0	10.1	-1.1
Wellington Electricity	4.1	6.9	-2.7
South Island			
Electricity Invercargill	7.7	0.6	7.0
Network Tasman	6.2	4.3	1.8
OtagoNet	3.2	4.7	-1.5
Aurora Energy	3.2	4.7	-1.5
Alpine Energy	6.9	10.2	-3.2
Electricity Ashburton	6.9	10.2	-3.2
Total	**6.7**	**6.8**	**-0.1**

Source: The CIE, Commerce Commission New Zealand.

Table 5.2 measures the annual forecasting errors made in the current regulatory period using the mean absolute percentage error and the root mean squared error. These measures show that forecast errors have generally been larger for regions that are reliant on agriculture and have particularly impacted by the shocks discussed above.

5.2 Magnitude of GDP forecasting errors, 2011 to 2013

	MAPE	RMSE
	Per cent	Per cent
Centralines	394.0	3.1
Eastland Network	394.0	3.1
Unison	130.2	2.9
Horizon Energy	91.4	2.5
Electricity Ashburton	67.4	1.5
Alpine Energy	67.4	1.5
The Lines Company	61.7	1.4
Wellington Electricity	566.6	1.4
Aurora Energy	109.8	1.3
OtagoNet	109.8	1.3
Vector	45.1	1.2
Nelson Electricity	51.5	1.1
Network Tasman	51.5	1.1
Powerco	47.5	1.1
Top Energy	39.8	0.9
Total	**12.9**	**0.3**

Source: The CIE, Commerce Commission New Zealand.

Population

Review of data source

Population forecasts are sourced from the New Zealand Census of Population and Dwellings at a territorial local authority (TLA) level. These forecasts are used to allocate population forecasts to each EDB's network area based on similar rules to those listed above:

- if an EDB network area is within a NZIER region, the regional GDP forecasts are attributed to the EDB.
- if an EDB network crosses regional boundaries, then the GDP growth attributed to an EDB is a weighted average of activity in each regional, where the weights depend on the share of the network area located in each region.

Building up population estimates from TLA level data suggests that population estimates for each EDB are likely to be more accurate than GDP estimates.

Review of forecast accuracy

Table 5.3 compares the cumulative growth in population growth over 1 April 2010 to March 31 2013 to forecasts of cumulative growth over the same period. The results suggest that the forecasts have been evenly distributed across regional jurisdictions, with population growth being noticeably lower than forecast in seven of the 16 jurisdictions. Forecasts have under-estimated population growth most significantly for Alpine Energy, OtagoNet, and Electricity Ashburton.

This is likely to reflect their proximity to Orion as the 2010/11 Canterbury earthquakes triggered large migration flows as people were displaced from earthquake-affected areas.[16]

5.3 Preliminary assessment of the accuracy of population forecasts

	Population 2011 to 2013	Population forecasts 2011 to 2013	Forecast error
	Cumulative per cent change	cumulative per cent change	Per cent points
Electricity Ashburton	5.8	2.0	3.8
Alpine Energy	2.1	0.2	1.8
OtagoNet	1.4	-0.2	1.5
Aurora Energy	3.4	2.1	1.3
Nelson Electricity	2.9	1.7	1.2
Electricity Invercargill	1.0	0.0	1.0
Network Tasman	2.7	2.1	0.6
Vector	4.6	4.6	0.0
Wellington Electricity	2.1	2.1	0.0
Eastland Network	-0.3	0.0	-0.3
Powerco	1.3	1.6	-0.3
Unison	0.5	0.9	-0.4
The Lines Company	-1.4	-0.8	-0.5
Horizon Energy	-1.7	-0.7	-1.0
Top Energy	-0.2	0.9	-1.1
Centralines	-1.5	-0.2	-1.3
Total	**2.9**	**2.8**	**0.1**

Data Source: Statistics New Zealand; New Zealand Commerce Commission forecasts.

Table 5.4 measures the annual forecasting errors made in the current regulatory period using the mean absolute percentage error and the root mean squared error. Two key findings are:

- the regions in closest proximity to Orion recorded the largest forecast errors.
- the magnitude of the errors are relatively small compared to the GDP forecast errors.

16 For more information, see: http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/SubnationalPopulationEstimates_HOTPAt30Jun13/Data%20Quality.aspx

– This partly reflects the fact that population growth is generally easier to forecast than GDP growth, as populations tend to grow at a more consistent pace over time

5.4 Magnitude of population forecasting errors

	MAPE	RMSE
	Per cent	Per cent
Electricity Ashburton	64.2	1.3
Electricity Invercargill	N/A	0.7
Alpine Energy	85.4	0.7
OtagoNet	98.5	0.7
Network Tasman	46.7	0.6
Nelson Electricity	43.1	0.6
Centralines	N/A	0.6
Horizon Energy	N/A	0.5
Aurora Energy	35.6	0.5
Top Energy	210.5	0.4
The Lines Company	49.3	0.3
Powerco	65.7	0.2
Wellington Electricity	24.4	0.2
Eastland Network	99.7	0.2
Unison	591.3	0.2
Vector	5.8	0.1
Total	**14.8**	**0.2**

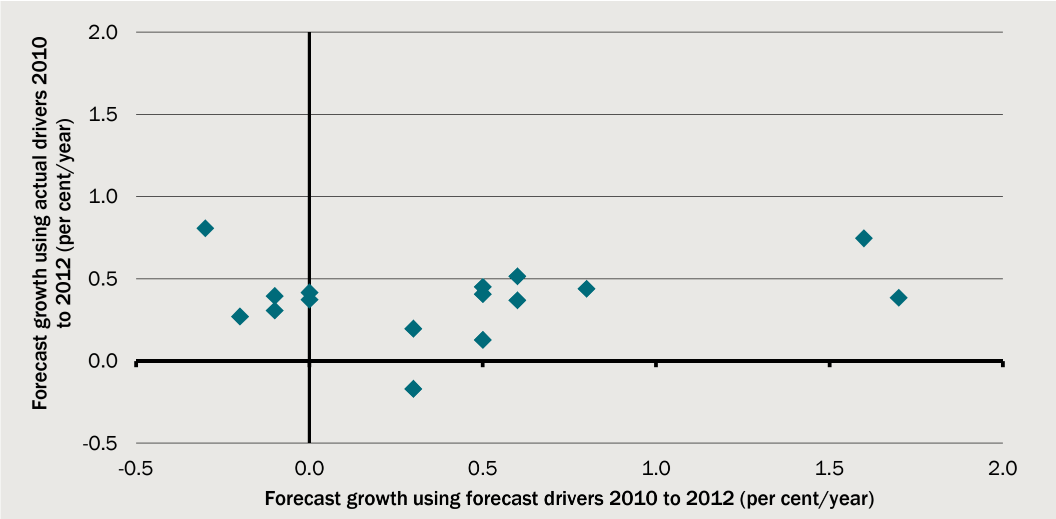
Sources: The CIE, Commerce Commission New Zealand.

Attribution of forecast errors to driver forecasts

The extent to which forecast errors can be attributed to errors in driver forecasts can be gauged by comparing the forecast performance of the CPRM when actual estimates for GDP growth and population growth are substituted for forecast values.

Chart 5.5 compares forecasts using actual GDP and connection points, relative to forecast GDP and connection points. The errors in drivers makes some difference to forecasts.

5.5 CPRM forecasts using actual and forecast drivers 2010 to 2012



Data source: The CIE, Commerce Commission New Zealand.

In terms of overall forecast errors, errors in drivers is a small component (table 5.6). The average across EDBs is a -1.4 per cent over-forecast of quantity with forecast drivers, compared to a 1.3 per cent over-forecast using actual drivers. These results imply that improvements in GDP and population growth forecasts are likely to only have a modest impact on the forecast performance of the CPRM if it remains in its current form.

5.6 Magnitude of forecasting errors, 2010 to 2012

	Forecast GDP & population	Actual GDP and connection points	Absolute difference
	Percentage points/year	Percentage points/year	Percentage points/year
North Island			
Powerco	0.0	0.4	0.4
Eastland	-0.1	-0.6	-0.5
Centralines	0.2	-1.0	-1.1
Top Energy	-0.7	-0.2	0.5
Unison	-1.3	-1.8	-0.4
The Lines Company	-0.5	-0.8	-0.4
Horizon Energy	-1.6	-2.1	-0.5
Vector	-1.4	-0.1	1.3
Wellington Electricity	-2.1	-1.8	0.4
South Island			
Network Tasman	0.1	0.2	0.1
Alpine	-3.2	-3.2	0.1
Ashburton	-7.4	-6.6	0.9
Aurora	-1.1	-0.8	0.2
Nelson Electricity	-1.0	-0.9	0.1
OtagoNet	-1.4	-1.3	0.1
Invercargill	-0.8	-1.2	-0.4

Source: The CIE, Commerce Commission New Zealand.

Key points

- **Forecasts of drivers of electricity revenue used by the Commission are subject to large forecast errors of their own, particularly given the long horizons being forecast.**
- **The NZ economy has been subject to a number of major shocks. Despite this, if forecasts of GDP and population are replaced with actual values, then this does not substantially improve the performance of the CPRM. The structural issues with the model imply limited gains from being better able to forecast drivers.**

6 Review of relationships used by the commission

Another possible source of error in the Commission's forecasts of constant price revenue growth is the assumptions made regarding:

- electricity use per individual connection point (ICP) and per capita
- the relationship between population growth and ICP growth; and
- the elasticity of constant price revenue to GDP.

This chapter reviews where possible the accuracy of these assumptions and the methodology used to estimate the elasticity of constant price revenue to GDP.

Elasticity of constant price revenue to GDP

The CPRM estimates changes in commercial and industrial electricity use by forecasting GDP growth and applying an estimate of the elasticity of constant revenue growth to GDP growth. This is in part due to data limitations, with the Commission noting that:

> We have not modelled industrial and commercial users separately because some distributors were unable to provide the split in revenue from commercial and industrial users in response to our information-gathering request.[17]

The model that has been used for the current regulatory period assumes that the elasticity is 0.52, while the current model proposed to be used for the next regulatory period assumes an elasticity of 0.73 (see table 5.1 below).[18] Data limitations make it difficult to assess how accurate this method has been over the current regulatory period. As a result, the remainder of this section focusses on reviewing the modelling methodology employed by the Commission and in turn the appropriateness of the estimates above.

Modelling methodology

The Commerce Commission has estimated the relationship between GDP and constant price revenue by using a panel data model with random effects. A random effects model considers both the variation between EDBs and over time to estimate the relationship between revenue and GDP.[19]

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17 Commerce Commission New Zealand, *Resetting the 2010-15 Default Price-Quality Paths for 16 Electricity Distributors, 2012.*

18 Commerce Commission New Zealand, *Low Cost Forecasting Approaches For Default Price- Quality Paths*, 2014.

19 A random effects model here assumes that individual specific effects are uncorrelated with GDP and drawn from a population with zero mean and constant variance.

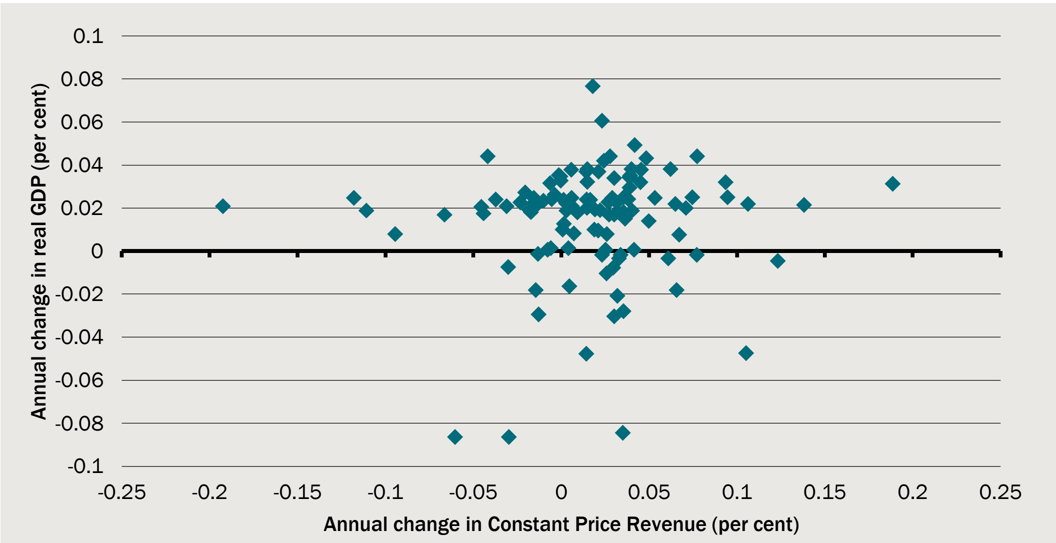
The Commission has modelled the relationship between GDP and revenue by relating the level of GDP to the level of revenue.

There is very little relationship between changes in constant price revenue and real GDP as shown by chart 6.1. If there was a relationship like that estimated by the Commission we would expect to see a positive relationship.

However, results are clustered in the area of 0-5 per cent growth in both real GDP and CPR. This indicates that the series is non-stationary because they have a trend rather than reverting back to a mean level. This is likely to be the cause of the estimated relationship in the level model. Both variables are generally trending upwards, however panel data regressions nonetheless do not support any significant relationship.

Note that the relationship is also unlikely to be reliable given that the data on constant price revenue that underlies this model is not consistent with correct measures of constant price revenue.

6.1 Relationship between Constant Price Revenue and real GDP



Data source: The CIE.

We have also tested other models to understand how stable the relationship between GDP and constant price revenue is. Testing these other model specifications and observing their performance relative to the Commission's model illustrates the poor ability of the Commission's model in predicting CPR in-sample. Extremely simple models not requiring driver data or forecasts (such as time trend models and autoregressive models) have superior performance according to their root mean standard error.

Models with a time trend

A model specification using *year* as an explanatory variable has superior performance compared to real GDP (lower RMSE, see table 6.2). The regression involving real GDP as the only explanatory variable may lead to a spurious result simply because it involves the estimation of the relationship between two non-stationary variables.

If both a time trend (through the *year* variable) and real GDP are included as explanatory variables, the GDP elasticity of revenue is estimated to be negative and GDP is not a statistically significant explanatory variable in this model. This result again indicates that the estimation of a significant relationship between revenue and GDP is likely to be spurious.

Autoregressive models

We have compared the fit of the model used by the Commission with the fit of a simple autoregressive model. An autoregressive model predicts the value of revenue in a period based on the revenue in one or more previous periods. The order of an autoregressive model is the number of previous periods of revenue that are included as explanatory variables in the model. An AR(1) model (that includes the first lag of revenue) provides a better in-sample fit using the RMSE than does the relationship between GDP and revenue (table 6.2).

Level and difference models

The Commission's model was estimated using a level relationship, in that it sought to estimate the relationship between a level of real GDP and a level of constant price revenue. The estimated elasticity and forecasts of GDP have been applied as a growth rate to the most recent revenue number. In such a case, rather than estimating the relationship between levels of the variables, it is often more suitable to estimate the relationship between changes in the variables.

Estimating a levels model yet forecasting using a growth rate is not a problem where the series are non-stationary (i.e. to do not revert back to some level or trend) but it is a problem where they are stationary.

- The weather influence would be expected to lead to some level of reversion. That is, a very cold year with high electricity use would likely lead to a reversion in subsequent years at normal weather conditions.
- Other impacts such as population and incomes would generate a non-stationary series. Analysis of non-stationary series can lead to spurious regression results. This is because when one non-stationary series is regressed on another a statistical relationship will be found, even where there is no real link (eg. Australian GDP and New Zealand electricity demand). Where variables are non-stationary applying growth rates to the latest available data is generally preferred.

Using the level of real GDP as an explanatory variable has a significant advantage over differences in that it takes account of lagged effects of GDP on revenue. In models using a real GDP growth variable, any lagged effects are ignored unless lagged GDP growth is included as an explanatory variable.

Table 6.2 compares the performance of the Commission's random effects model to alternative specifications of the model of commercial and industrial demand (using constant revenue line charge as a proxy). It shows that that the RMSE of most of the alternative models is lower than the model used by the Commission.

6.2 Summary of performance of alternative models

Dependent	Model structure	Obs.	Explanatory variables	RMSE	
				Level models	Change models
			Variable (sign, significance)		
Commission	Random effects	127	GDP(+, *)	0.061	
Commission	Fixed effects	127	GDP(+, *)	0.061	
Commission	Random effects	127	Time trend (+, *)	0.050	
Commission	Random effects	127	GDP(-,) Time trend (+, *)	0.050	
Commission	Random effects	113	Lagged revenue (+, *)	0.063	
Commission	Random effects	113	Lagged revenue (+, *) 2nd lag of revenue (+,)	0.048	
Δ Commission	Random effects	113	GDP(+,) HDD(-,)		0.064

Note: In the explanatory variables column the terms in the brackets indicate the sign of the coefficient (positive or negative) and whether the term is significant or not (* indicates significant at 5 per cent level of significance, blank indicates not significant).
Source: The CIE, Commerce Commission New Zealand.

Other limitations with the methodology

Constant price revenue from all users was used instead of constant price revenue from commercial and industrial users only, despite this being applied to commercial and industrial users only. Residential revenue growth (per cent) has a smaller standard deviation than commercial and industrial revenue growth. The estimated relationship between real GDP and total revenue will not be an accurate proxy for the relationship between real GDP and commercial and industrial revenue.

Line charge revenue deflated by CPI was used as a proxy for constant price revenue, when actual price changes have often been well in excess of CPI growth, particularly over the 2004 to 2009 period. The effect of this is that the constant price revenue measure is substantially inaccurate. The effect will be that growth in the constant price revenue measure used includes the effect of price increases above the CPI.

No allowance was made for the impact of weather in undertaking analysis. Weather conditions may affect revenue based on the effect of climate of use of heating and cooling technology. We have constructed a HDD variable for each index and tested it in alternative model specifications, and this is discussed further in chapter 6.

Electricity use per residential ICP

The CPRM has assumed that there is no change in electricity use per residential user over the current regulatory period. According to the Commission:

> Change in the electricity use per residential user was assumed to be zero based on historical trends from the Ministry of Business Innovation and Employment.

Over the coming regulatory period, the Commerce Commission appears to currently be adopting a qualitative approach to forecasting electricity use per residential user noting that:

> Our current view is that electricity consumption by the average residential user is unlikely to fall over the next 5-7 years. Electricity price increases are starting to moderate, economic activity is picking up, and electric cars are becoming viable. Taken together, our expectation is that electricity use per user is more likely to remain broadly constant.

Data collected by the Commission in 2012 from EDBs appears to be broadly consistent with the data provided by MBIE in suggesting that the national intensity of household electricity usage was constant leading into the current regulatory period.

Table 6.3 below shows estimates of the average electricity use per residential user over 2008 and 2011 (regulatory years) using the results of using data collected by the Commission in 2012. While the short sample period makes it difficult to make definitive conclusions about underlying trends, electricity use per ICP was broadly constant across most EDBs in the period leading into the current regulatory period.

6.3 Electricity supplied per residential ICP

	2008	2009	2010	2011	2008 to 2011
	MwH/ICP	MwH/ICP	MwH/ICP	MwH/ICP	Per cent
Alpine Energy	12.5	12.8	13.3	13.5	8.0
Aurora Energy	8.9	8.7	8.9	8.5	-4.5
Centralines	7.5	7.8	8.1	7.7	2.7
Eastland Network	6.3	6.2	6.4	6.3	0.0
Electricity Ashburton	8.3	8.5	8.6	8.5	2.4
Electricity Invercargill	13.7	13.8	14.1	13.7	0.0
Horizon Energy	6.2	6.3	6.3	6.2	0.0
Nelson Electricity	3.5	4.5	5.3	4.9	40.0
Network Tasman	7.4	7.4	7.6	7.2	-2.7
OtagoNet	10.5	10.5	10.8	10.4	-1.0
Powerco	8.1	7.8	7.7	8.0	-1.2
The Lines Company	na	na	na	na	-
Top Energy	8.0	7.8	7.9	7.6	-5.0
Unison	7.0	7.2	7.5	7.2	2.9
Vector	7.4	7.4	7.5	7.3	-1.4
Wellington Electricity	7.5	7.6	8.0	7.6	0.8

Source: Commerce Commission New Zealand.

The 2012 data available for small and medium connection points indicates falling consumption per ICP (table 6.4).

6.4 Electricity suppled per ICP

	2008	2009	2010	2011	2012
Electricity supplied					
Small Connection Points (MWh)	9 961 294	9 614 474	10 239 595	10 150 270	10 060 930
Medium Connection Points (MWh)	3 017 709	2 827 985	3 072 794	2 916 459	2 944 264
Number of ICPs					
Small Connection Points (No. ICPs)	1 298 433	1 316 416	1 321 543	1 325 069	1 316 723
Medium Connection Points (No. ICPs)	95 787	96 600	103 203	105 851	124 015
MWH/small and medium ICP	9.31	8.81	9.34	9.13	9.03

Note: Total across all EDBs except Orion.

Source: The CIE; Electricity Information Disclosure Summary Database 2008 to 2012, Commerce Commission New Zealand.

The reasons for changes in residential electricity use have not been examined in detail to our knowledge. There are a number of government programs that may have some effect (box 6.5).

6.5 Energy reduction programs

The recent experience of EDBs outlined above is consistent with a number of incentives have been provided by the New Zealand Government in recent years to encourage homeowners to insulate their properties.

Warm Up New Zealand Programs

Warm Up New Zealand: Heat Smart was a four-year program that ran from 2009 to 2013. Under the programme, subsidies were provided for the cost of retrofitting insulation and/or installing clean heating for pre-2000 houses. From an initial target of insulating 188,500 New Zealand homes, the program has managed to insulate 235,000 for the same budget of $347 million. The Warm Up New Zealand: Healthy Homes programme is a new initiative that provides targeted subsides to low-income households for home insulation, particularly households occupied by children and/or the elderly. The 2013 Budget allocated $100 million of operating funding over three years

Other EECA initiatives

Other EECA initiatives that are likely to have improve energy efficiency to some extent include:

- Product standards and labelling
- RightLight
  - the RightLight campaign uses information provision and advertising to encourage consumers to find energy efficient lighting alternatives that serve their needs, across both residential and business.
- ENERGYWISE information
  - EECA's ENERGYWISE information program uses the ENERGYWISE website and other channels such as brochures, advertising and media releases to provide independent, reliable information about their energy choices.
- The Energy Spot
  - the Energy Spot is a television segment that brings the energy efficiency message to the mainstream audience. It has been on air since 2009 and is estimated to have been viewed by around 2.4 million New Zealanders.

Connections growth versus population growth

In the CPRM, population growth of the regions(s) where an EDB network is located is used as a proxy for the growth in the number of residential ICPs. This is partly due to the availability of population forecasts at a detailed regional level.

In theory, population growth can differ from ICP growth for a number of reasons including:

- changes in average household size

  - a decline in the average number of people per household would imply that greater growth in the number of ICP will be associated with a given change in the population. This would be partly offset by an expected decline in revenue per ICP due to the reduced number of people per dwelling.
- the prevalence of embedded networks
  - some apartment buildings have a single ICP that covers multiple dwellings throughout the complex. As a result, an increase in the number of apartments as a share of dwellings would be expected to reduce ICP growth relative to population growth.
- incorrect coverage area
  - ICP growth within a network area may differ from estimated population growth if the network area is somewhat different to the regions used to estimate population growth.
- energy alternatives
  - Increased use of energy alternatives such as solar could lead to a reduction in the growth of residential ICPs.

The way that the Commission uses population growth has a two-fold impact.

- The Commission uses population as a proxy for revenue from fixed charges for residential customers
- The Commission uses population as an additive factor for residential use per connection. That is, total residential use and hence volume revenue will be the sum of the ICP growth and the growth in use per ICP.

The reasons why population and ICP might diverge are not equally important for both these uses.

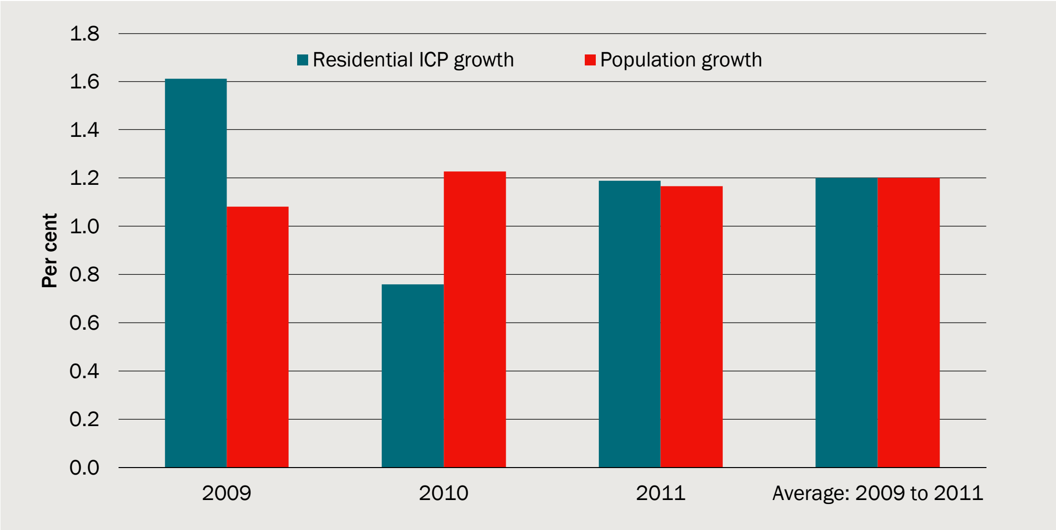
6.6 Impact of population proxy on fixed and volume revenue

	Population applied to fixed revenue	Population applied to volume revenue
Changes in household size	Would impact	Would have limited impact, as energy use is largely per person
Embedded networks	Would impact	Would have limited impact as popn would still be covered by EDB
Incorrect coverage area	Would impact	Would impact
Energy alternatives	Would impact	Would impact

The use of population growth is a well-established practice for electricity forecasting and is used by most distributors in the Australian context and the Australian Energy Market Operator. In New Zealand, however, population growth appears to have consistently overestimated the growth in the average number of residential ICPs.

The performance of population as a driver of connections for forecasting foxed revenue can be assessed through considering the relationship between connections and population historically. Data is available from 2008 to 2011 for all EDBs. Chart 6.7 below compares annual growth in population and residential ICPs across the total network area over this period. On average, annual population growth has been similar to the rate of growth in ICPs, though some variation has been observed year to year.

6.7 Population versus residential ICP growth



Data source: Section 53ZD Information Request April 2012

On an individual EDB basis, this relationship is less robust. The average (absolute) difference between the population growth and residential connection point growth across EDBs is 0.7 per cent per year. This is surprisingly high, as average population growth is a moderate 1.2 per cent per year. An EDB with a less than average error and population growth of 1.2 per cent per year could have ICP growth in the range of 0.5 per cent to 1.9 per cent per year. This is a substantial margin of error.

Key points

- **There is little substantive evidence for the main assumptions made by the Commission about key relationships**
  - **the relationship between GDP and commercial and industrial revenue is not robust**
  - **the evidence for assuming an unchanged future electricity use per residential customer is limited and there may be differences across EDBs that have not been considered**
  - **the relationship between population growth and ICP growth is surprising weak**

7 Alternative models

We have considered the use of alternative *statistical* models to forecast constant price revenue (CPR). These models will not yield suitable forecasts for regulation at this stage because:

- the dependent variable currently used in analysis is not an accurate measure of constant price revenue, as discussed in Chapter 2 , and
- the preliminary testing undertaken has not found any model that provides a good fit using the constant price revenue measure constructed in this project.

Given this, in sketching out alternative models we highlight what we have undertaken and the preliminary findings of this work. We would consider that while these models have a lower error than the Commission's models, they are not sufficiently well-developed to justify usage in setting default price paths.

Before doing this, we note that the Commission and the alternative models tested are for *total quantity* and should be applied as such, rather than only to C&I quantity.

Following consideration of alternative statistical models we set out an alternative not based on a statistical model.

Statistical models for forecasting

Selection of the dependent variable

The dependent variable used to model the relationship between revenue and GDP is Constant Price Revenue (CPR). This is a measure of real revenue, in that it is intended to exclude price effects. However, given that electricity distribution prices have risen faster than the CPI, the data used by the Commission in their modelling is not an accurate measure of constant price revenue.

In particular, many distributors have repeatedly breached the default price paths set by the Commerce Commission, particularly over the 2004 to 2010 period (table 2.4 and 2.5). In addition, between 2004 and 2009 under the Thresholds regime EDBs could increase prices by CPI-x and x ranged from -1 to +2. Price increases in breach of the default price paths and other general price increases have exceeded the CPI, and therefore the process of using CPI as a deflator to transform total line charge revenue into constant price revenue. The quality of results obtained from the model is clearly reliant on an accurate dependent variable. The substantial inaccuracy of the measure of CPR used means that modelling results are inaccurate and potentially biased.

Therefore, the construction of alternative forecasting models based on the same dependent variable seems unlikely to yield a suitable means of forecasting revenue for the purposes of setting the default price paths. Rather, a more accurate measure of constant price revenue or a different type of dependent variable (such as electricity supplied) should be determined, as set out in Chapter 2. The more appropriate measure of constant price revenue involves calculating weighted average demand as follows:

$$WQ_t = \sum_{j=(r,c,i)} \frac{Q_t^j}{Q_0^j} . \frac{R^j}{R} + \sum_{j=(r,c,i)} \frac{N_t^j}{N_0^j} . \frac{RN^j}{R}$$

We have undertaken preliminary testing using this alternative measure. It is constrained to cover only the period 2008 to 2012, which means it has a limited sample.

Explanatory variables

Weather

Weather, and more specifically temperature is generally found to be a significant driver of electricity demand, and therefore revenue. Below a certain threshold declining temperatures are expected to lead to increasing use of heating appliances, and therefore higher revenue should occur during years with colder winters.

Therefore we have constructed a variable for 'heating degree days'. Heating degrees is defined as the number of degrees that the mean temperature is less than 16.5 degrees. If heating degrees is negative, it is instead set to 0 for that day. Then heating degree days for each year is the sum of heating degrees for all days within the year.

The heating degree days measure is widely used in electricity demand forecasting by bodies such as AEMO.[20]

A year is deemed to be between April of one year and March of the next. For example, 2013 is between 1st April 2013 and 31 March 2014. This aligns to the period defined as a year for the revenue data (based on the fiscal year).

The log transformation of the *HDD* variable was included in the models we have tested given that the log transform of revenue is the dependent variable. Log specifications in such models have been found to have superior performance in other forecasting exercises.[21]

The HDD variable is a significant explanatory variable when it is added to the Commission's commercial and industrial revenue model (a random effects model), and it decreases the RMSE of this model. However, the sign of the variable is not meaningful, and, as discussed above the dependent variable is inaccurately measured.

Heating degree days were generally found not to be a significant predictor of CPR or electricity supplied at a 95 per cent level of significance. This result held among almost all

20 AEMO 2014, National Electricity Forecasting Report, June 2014.

21 AEMO 2013, National Electricity Forecasting Report, June 2013.

models tested including models using both the change and the level of revenue/electricity supplied as a dependent variable.

Electricity prices

We have not constructed a measure of electricity prices for each EDB's area.

Models that improve fit over Commission model

Any number of models can be fit that have a lower in-sample RMSE compared to the Commission's statistical analysis, as set out in the previous chapter. These include:

- a yearly time trend
- a yearly time trend specific to each EDB
- an AR(1) model of revenue

We have run many other specifications covering the following:

- dependent variables ranging from the Commission's, CIE preferred and electricity supplied
- level models versus change models
- inclusions/exclusion of time trends, weather impacts, GDP.

However, we would not consider that there are any strong empirical findings that come from the analysis conducted to date.

Table 7.1 presents the results from selected model specifications we have evaluated. The performance of models that use the CIE preferred dependent variable is not directly comparable to the performance of the Commissions model using the root mean squared error (RMSE). Both models use the natural log transform of the dependent variable, and thus the RMSE gives a percentage error, however because they are measuring different things (quantity in MWH and real revenue respectively) they are not strictly comparable.

7.1 Summary of performance of alternative models

Dependent	Model structure	Obs.	Explanatory variables	RMSE			
				Unweighted level	Weighted level	Unweighted change	Weighted change
			Variable (sign, significance)				
Commission	Random effects	127	GDP(+, *)	0.061			
CIE	Random effects	71	GDP(-,)	0.018			
CIE	Random effects	69	GDP(-,) HDD(-,)	0.016			
CIE	Fixed effects	71	GDP(+,)	0.018			
CIE	Fixed effects	71	GDP(+,) HDD(-,)	0.016			

Dependent	Model structure	Obs.	Explanatory variables	RMSE			
				Unweighted level	Weighted level	Unweighted change	Weighted change
CIE	Fixed effects	71	Time trend (+,)	0.018			
CIE	Fixed effects	69	Time trend (+,) GDP (-,)	0.018			
CIE, weighted	Fixed effects	71	GDP(+, *)		0.012		
CIE, weighted	Fixed effects	69	GDP(+, *) HDD(-,)		0.012		
Δ CIE	Fixed effects	56	Δ GDP(-,)			0.028	
Δ CIE	Fixed effects	54	Δ GDP(-,) Δ HDD(-,)			0.025	
Δ CIE, weighted	Fixed effects	56	Δ GDP(-,)				0.019
Δ CIE, weighted	Fixed effects	54	Δ GDP(-,) Δ HDD(+,)				0.017
CIE	No effects		EDB-specific time trend (+/-,) [a]	0.019			
CIE	Fixed effects	71	$GDP_{Commercial}$ (+,*) $GDP_{Industrial}$ (+,) [b]	0.012			
CIE	Fixed effects	69	$GDP_{Commercial}$ (+,*) $GDP_{Industrial}$ (+,) HDD (-,)	0.012			

[a] The EDB-specific time trends are various positive and negative. The EDB-specific time trend parameters fail a joint F test (we fail to reject the hypothesis that all EDB's have the same time trend effect).

[b] These models include both GDP from commercial production and GDP from industrial production, rather than just a combined GDP variable (as is used in other cases).

Note: In the explanatory variables column the terms in the brackets indicate the sign of the coefficient (positive or negative) and whether the term is significant or not (* indicates significant at 5 per cent level of significance, blank indicates not significant).

Source: The CIE.

We consider that the performance of the models using the CIE preferred dependent variable is superior, however it is insufficiently robust for a forecast model. Few models show any drivers that are statistically significant and economically meaningful.

- **No empirical specification that we have tested is sufficiently robust for a forecast model for constant price revenue**

An alternative forecasting model

The lack of a strong empirical forecasting model suggests that there is a need to reconsider the approach to forecasting more broadly. This could include:

- reconsidering the regulatory structure and how forecast risks are allocated between EDBs and customers; and

- developing a forecasting approach that implicitly allows for lower bias over a longer period.

The first is outside the scope of this paper, although our findings are strongly supportive of seeking to undertake such a reconsideration. This is both because the current basis for forecasts is very weak, improvements are likely expensive and the drivers are outside the control of EDBs.

The second is within the scope of this paper and below we set out how this could be undertaken.

Forecasting for regulatory purposes aims to ensure that EDBs are able to recover the efficient costs but no more of providing services from customers. Bias in forecasts is a particularly substantial concern for this objective, because it implies persistent errors in one direction. Inaccurate forecasts are less problematic because if inaccuracy is not systematic then an EDB would, over a sufficiently long period, recover efficient costs from customers.

A natural approach that seeks to minimise forecast bias is to relate the forecasts used to the past rate of growth in constant price revenue. This means that an EDB always achieves the revenue growth forecast but with a lag.

- **We propose a low cost model that uses past revenue growth as the forecast of future revenue growth.**

This construct is set out below and then its merits are tested.

Forecasts using lagged constant price revenue growth

Suppose an EDB achieved constant price revenue growth of 3 per cent per year over the last regulatory period. The forecast approach proposed would then set the forecast for the next regulatory period as equal to 3 per cent per year.

There is precedent in such an approach, for State Water in NSW. In this case, State Water faced substantial risk to revenue from drought and climate change, which it could not manage and which could not be accurately predicted.

- Climate change could lead to persistent forecast errors and hence bias
- Inability to accurately forecast and the variability of outcomes meant that the period of time over which forecast errors would balance out would be very long.

A forecasting approach was developed to use a moving average of past actual quantities of demand. This meant that State Water's forecasts would be adaptive to climate change, but with a lag, and the risk of over or under-recovery of revenues was minimised over a longer time period.[22] For example, if there was a drought, State Water would substantially under-recover revenue as the quantity of water sold would fall. This would then feed into higher subsequent prices because forecasts of quantities for the next

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22 The CIE, *State Water consumption forecasts for the 2010 pricing determination*, prepared for State Water, 2009, http://www.thecie.com.au/content/publications/Final_Report_State_Water_14_Sept_09.pdf

regulatory period would reflect this drought. This approach was accepted by the NSW regulator, the Independent Pricing and Regulatory Tribunal.

This approach is low cost. The only cost involved is seeking to accurately measure the historical growth in constant price revenue.

Performance of alternative forecasting approach

We have constructed a hypothetical revenue projection model to determine the conditions under which this framework is revenue neutral. We have assessed the revenue implications of the model (where forecast revenue growth is equal to revenue growth over the previous regulatory period) against a statistical model. The statistical model is defined by the level of bias and the accuracy of the forecasts as follows.

$$Forecast_{t,edb} = Actual_{t,edb} + Bias + Error$$

That is, the forecast is aligned to the actual but with some level of bias and some level of error. The expected value of the error is equal to zero.

We then restrict forecasting models to lie between:

- a model with 100 per cent explanatory power. That is, forecasts have zero bias and zero error; to
- a model with significant bias (1 per cent per year in either direction) and significant error (explaining none of the variation in historical data).

The Commission's current model would fall towards the latter end of this range.

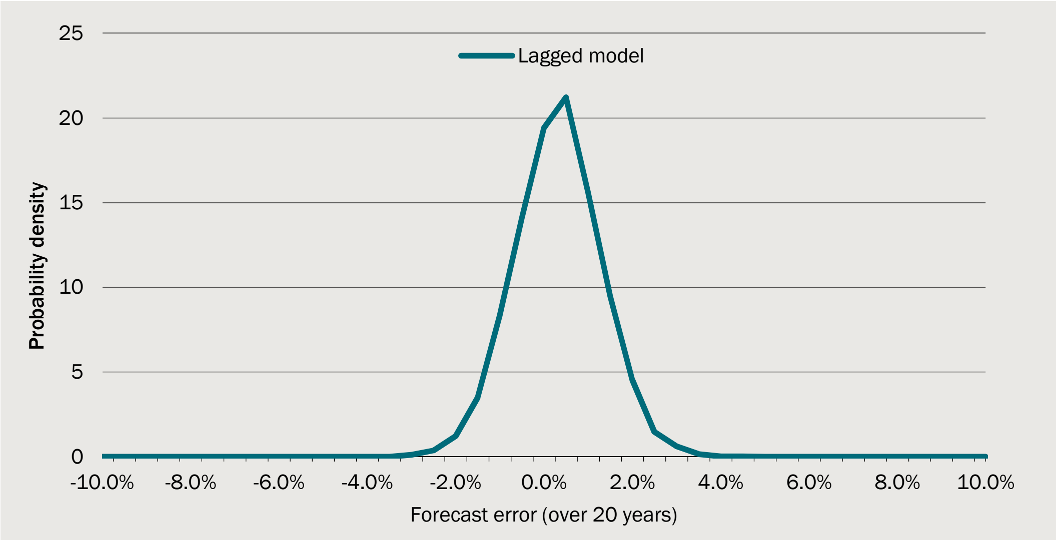
Forecasts are then assessed as follows.

1 We construct 1000 simulations of revenue growth randomly over a 20 year period.
2 We construct the forecasts using the lagged growth model
3 We construct forecasts using statistical models for different levels of bias and accuracy.
4 We then compare the mean of the difference in forecast revenue and actual revenue for all models using:
   – the expected value of this 20 year mean over the 1000 simulations
   – the distribution of this 20 year mean over the 1000 simulations.

A preferred forecasting model would have an expected value of the mean difference equal to zero and a narrow distribution of this 20 year mean.

The performance of the lagged revenue growth model is shown in chart 7.2. Over a 20 year period, this model would mean a distributor would generally receive (and customers would generate) revenue within plus or minus 2 per cent of the anticipated revenue (i.e. efficient costs). The expected error of this model is zero — that is, it is unbiased.

7.2 Forecast error of lagged revenue growth model



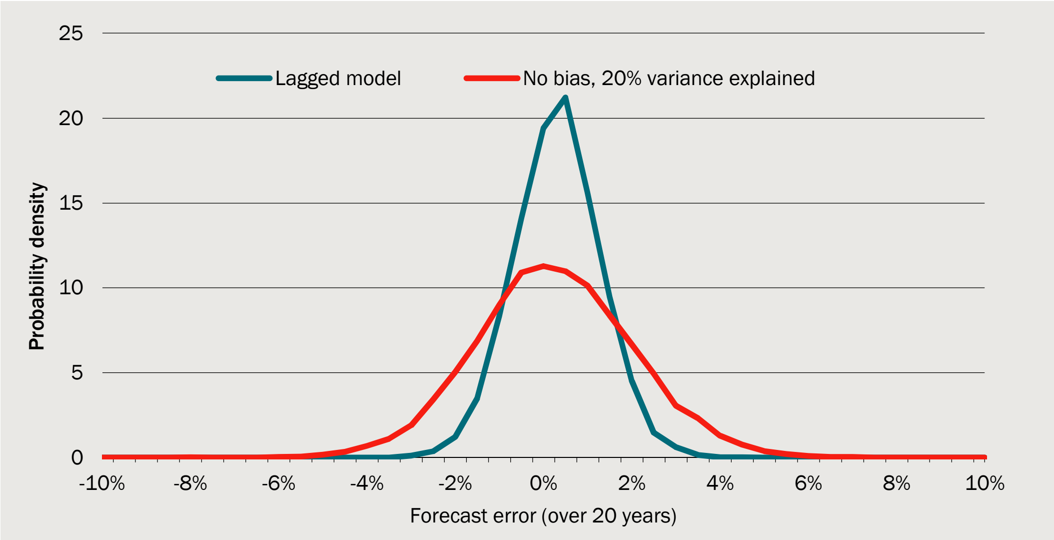
Data source: The CIE.

We have then considered how the lagged growth in constant price revenue aligns with statistical forecasting models.

- An unbiased statistical model that explained 20 per cent of the variation in constant price revenue growth performs less well than the lagged revenue model (chart 7.3). While it has an expected error of zero (by assumption of being unbiased), it leads to a greater possible spread in forecast errors and hence the extent to which revenue matches costs over a 20 year period.
- A biased statistical model — whether this is bias for a particular EDB or for all EDBs performs substantially less well than the lagged revenue model (chart 7.4). If there is any bias then the statistical model would not lead to an EDB being able to recover their efficient costs in expectation.

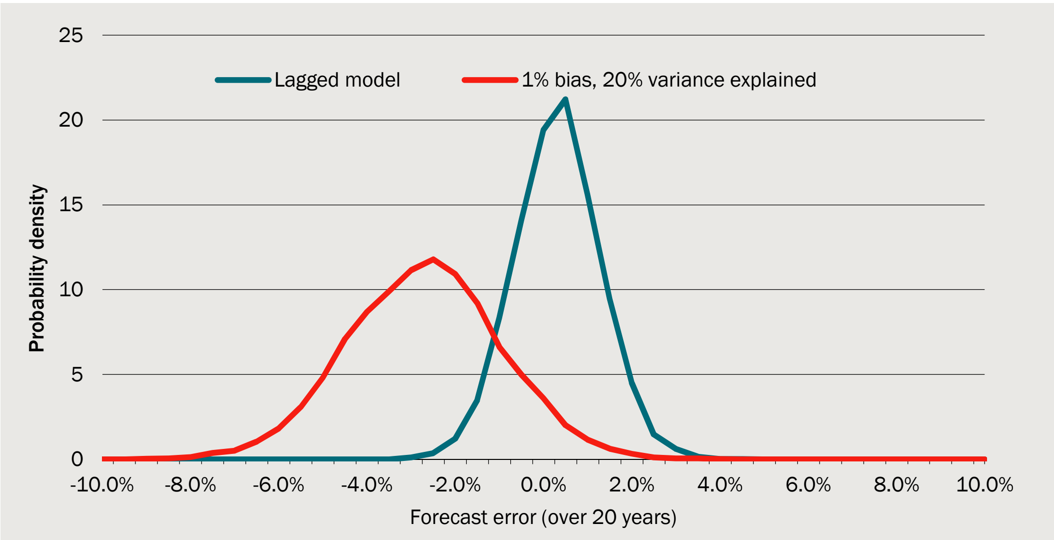
The Commission's model would, on the arguments presented in this report, likely have some level of unknown bias for particular EDBs and explain less than 20 per cent of the variation in outcomes.

7.3 Lagged revenue versus unbiased statistical model



Data source: The CIE.

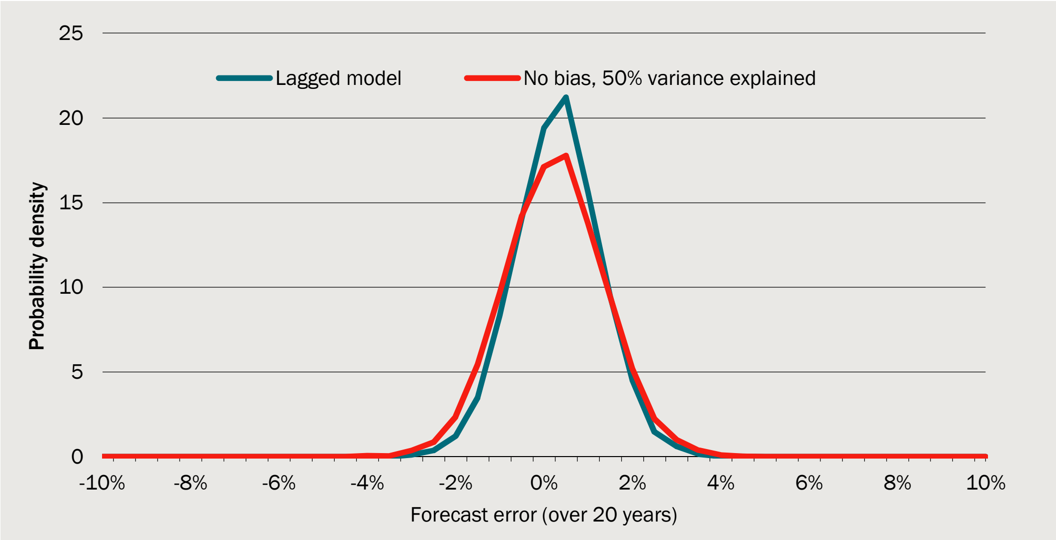
7.4 Lagged revenue versus biased statistical model



Data source: The CIE.

An alternative way to view this is how good would a statistical forecasting model have to be in order to be preferred to using lagged revenue growth? As shown in chart 7.5, a forecasting model that explained 50 per cent of the variance of outcomes and was unbiased would provide a similar level of accuracy as using the lagged revenue growth model.

7.5 Lagged revenue versus accurate unbiased forecasting model

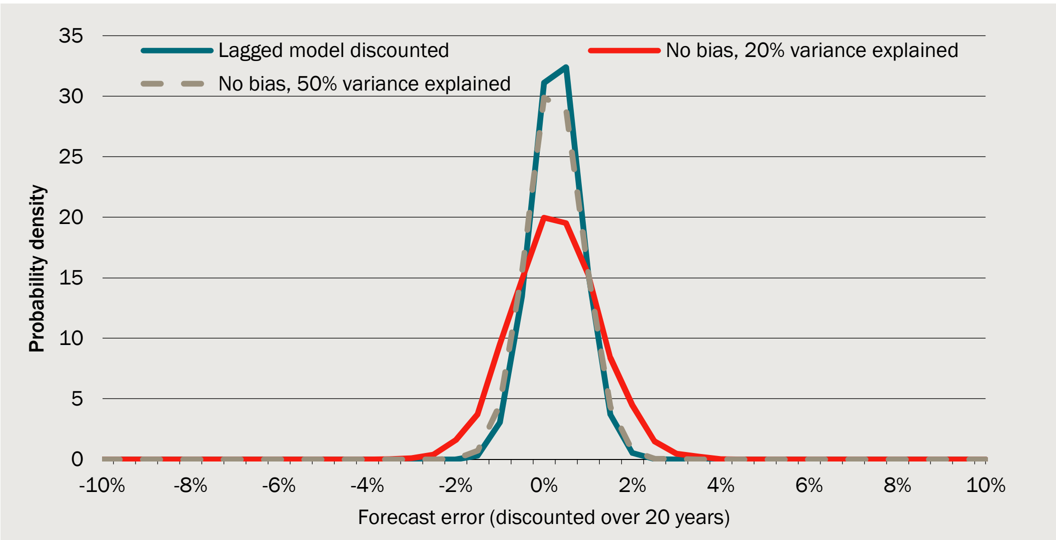


Data source: The CIE.

The evaluation of forecasting performance above is based on undiscounted forecast errors. In reality, errors earlier in the period are likely to be weighted more highly by EDBs and customers than errors late in the period because of discount rates.

In chart 7.6 we show the evaluation if a discount rate is applied of 7 per cent, to take outcomes from a 20 year period back to values in year zero. The conclusions remain robust to this, with the lagged revenue model performing similarly well to an unbiased forecasting model that can explain 50 per cent of the variation of revenue growth for an EDB.

7.6 Lagged revenue versus unbiased models, with discounting for time



Note: A 7 per cent real discount rate has been used.

Data source: The CIE.

Key points

- **Alternative empirical specifications of forecasting models can improve on the forecasting model of the Commission but are not at a stage whereby they could be considered to be reliable enough for regulatory purposes.**
- **An alternative low cost forecasting approach is to use lagged constant price revenue growth for the last regulatory period as the forecast for the constant price revenue growth for the next regulatory period.**
- **Testing of this specification finds that it performs better than a statistical model because it can be guaranteed to be unbiased over time for each EDB and produces a less dispersed range of possible outcomes for forecasting errors.**
- **The Commission should consider the use of this approach using a robust calculation of constant price revenue growth over the most recent regulatory period.**

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