Competition benefits in the Regulatory Test

Note for TransGrid

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Frontier Economics Network

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1. Introduction

This note sets out a proposal for how the benefits of competition could be included in the assessment of a regulated augmentation in the ACCC's Regulatory Test. The proposal is not intended to provide a detailed explanation of the economic concepts presented here. The intent is merely to present the basic economic concepts to determine whether the proposal is worth developing further.

The TransGrid submission on the ACCC's Regulatory Test Issues Paper discussed a process whereby price reductions brought about by additional competition stimulated by an augmentation could be used to calculate an increase in the sum of consumer and producer surplus – an increase in net market benefit. Whilst price reductions may lead to second or subsequent round benefits to the economy as a whole, these benefits are typically not included in orthodox cost-benefit analysis. Therefore, the proposal in this paper will be restricted to showing how competition-driven price reductions could increase surpluses in the electricity market.

The TransGrid submission noted that determining the impact of various investments on market outcomes could be difficult, but that this could be achieved through game theoretic modelling of the NEM. More specifically the purposes of this note are to introduce the concept of game theoretic modelling in the NEM and to provide a worked example of this approach in relation to a hypothetical interconnector.

- Section 2 briefly outlines the salient features of the current Regulatory Test and how competition benefits would change the test;
- Section 3 discusses the key ideas in game theory and discusses how game theory has and could be applied; and
- Section 4 provides a detailed worked example for a 400 MW interconnector between the Victoria and Snowy regions on the NEM.

2. Application of the Regulatory Test

There are two separate but related areas where the current Regulatory Test could be said to not include the full market benefits brought about by a proposed augmentation:

- Non-competitive bidding – the test only allows limited consideration of the benefits brought about by making generator bidding behaviour more competitive; and
- Difficulty of modelling price elasticity of demand – without adequately accounting for the demand response to lower prices, the market benefits of lower prices brought about by an augmentation are likely to be significantly understated.

In combination, these two factors could mean that market benefits of an augmentation are understated to the extent that an option that actually maximised net market benefits did not pass the Regulatory Test.

2.1. Non-competitive bidding

As it stands the Regulatory Test requires net market benefits to be calculated on the basis of competitive costs of supply[1], although non-competitive behaviour can be used to develop 'market-driven market development scenarios', which in turn are used to determine 'modelled projects' as required by the Test.[2]

In the 'Commission's considerations' for the Regulatory Test, the Commission said:

> "…cost/benefit analysis does not rely on market prices where there is good reason to believe these prices maybe distorted by a market failure (eg use of market power). For this reason, the Commission has based the regulatory test on the notion of a net public benefit derived from a comparison of the economic costs associated with each alternative. The Commission has moved away from a test based on price outcomes which may not reflect competitive market behaviour but may include distortions due to behaviour reflecting the use of market power."[3]

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[1] Note (1)(b)(iii).

[2] Notes (5)(c) and (6)(b).

[3] Section 3.1, "Issues for the Commission".

Therefore, focussing only on savings in variable costs for the time being, the Regulatory Test includes the underlying cost savings brought about by less constrained dispatch.

At the same time, the Commission acknowledged non-competitive behaviour in the formulation of market development scenarios. Consequently, the Regulatory Test requires the use of a 'least-cost market development scenario' and 'market-driven market development scenarios'. The latter should vary from the former only in the presence of market power. The Commission did not seem to find any inconsistency between calculating market benefits on the basis of underlying economic costs whilst at the same time allowing forecasts of future modelled projects to be based on projections of likely market outcomes.[4]

All of this suggests that although non-competitive market behaviour can be taken into account in working out the timing and nature of 'modelled projects', once that has been done, only competitive costs are taken into account in calculating net market benefits.

However, to the extent that increased competition lowers *actual market prices*, this could lead to increased demand and greater market benefits than would be the case if it were assumed that the market were perfectly competitive. This is illustrated in Figure 1 below.

2.2. Demand elasticity

As indicated above, taking the competitive price effects of an augmentation into account is only likely to be significant if demand is assumed to respond to lower prices. Elasticity is *generally* a long-term concept in electricity markets, as load in any appreciable quantity cannot presently respond to higher prices in real time. However, these benefits should not be ignored just because they occur in the longer term.

Indeed, the Regulatory Test requires that demand forecasts are taken into account in determining net market benefit, including 'reasonable assumptions regarding price elasticity'.[5] However, in practice, this is difficult to do if actual market outcomes are ignored. Demand forecasts tend to be based on current demand levels, which in turn are reflective of current market prices, not

[4] Section 3.5 Modelling of alternative scenarios.

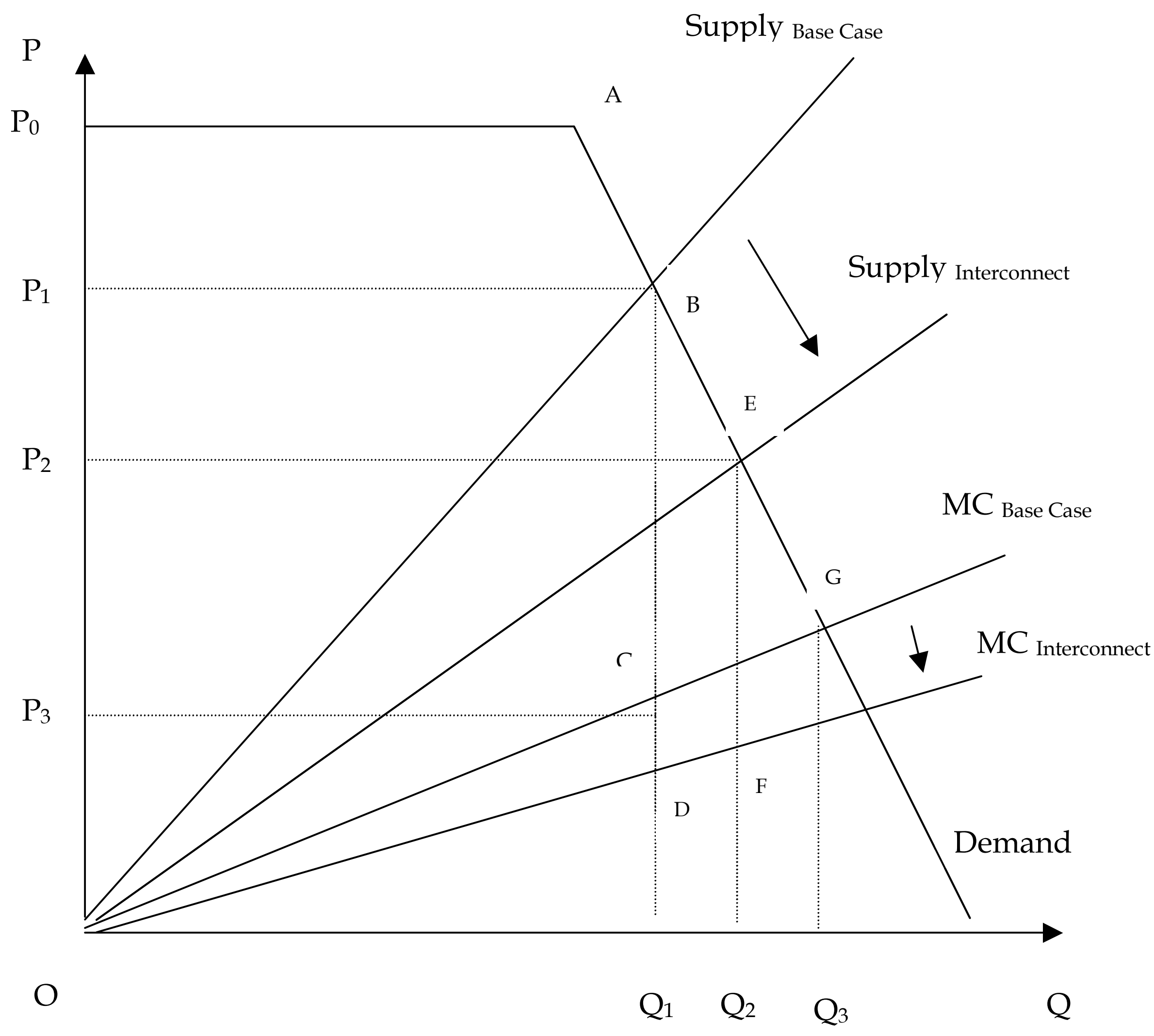
[5] Note (1)(b)(i).

underlying economic costs. Therefore, whilst a number of demand forecasts may be used in an application of the Regulatory Test, these are not typically contingent on particular price outcomes.

This suggests that the Regulatory Test does not take account of the increases in demand that could follow from a fall in prices brought about by more competitive market behaviour. However, if actual market outcomes were considered in the test as part of a 'competitive benefits' analysis, it would be more practicable to take account of demand response and the associated market benefits.

Consider the following diagram, which illustrates these two factors from a static perspective.

Figure 1: Competition benefits



Due to the presence of market power, the market supply curve is higher at all points than the corresponding marginal cost of supply.

Prior to the interconnector, market equilibrium is at B[6] and total market benefits are P_0ABCO. The area P_0ABP_1 is consumer surplus and the area P_1BCO is producer surplus.

Then assume that the interconnector has the dual effect of reducing the marginal cost of supply and increasing competition, thereby rotating both the supply curve and the MC curve clockwise.

Under the Regulatory Test as its stands, only the fall in costs of competitively supplying the load is taken into account. Taking demand as given and ignoring fixed costs, gross market benefits are now P_0ABDO and the net market benefits of the interconnector are CDO. As the diagram shows, it is not practicable to take demand response to higher prices into account, because the Test artificially abstracts market power away from the determination of market benefits – there is no demand curve going through point C. Forecast demand (Q_1) is based on current market prices (P_1), not on what the price would be in a competitive market (P_3). To inject price elasticity into the conventional market benefit calculation would require the creation of a 'synthetic demand curve' going through point C to help estimate how demand would increase if the competitive market price fell due to the augmentation. This is likely to be highly contentious and arguably meaningless. It would mean that market benefits were being assessed in a purely hypothetical manner.

However, incorporating the effects of competition on *actual market outcomes* and considering demand elasticity, the new equilibrium is at E and total market benefits are P_0AEFO, an increase of BEFOC over the base case and an increase of BEFD over the conventional calculation of the net market benefit of the interconnector. In practice, the marginal cost curves may vary slightly, so the better way to calculate the "competition benefits" of an augmentation is to subtract conventional market benefits (CDO) from total market benefits (BEFOC).

[6] The point B and quantity Q_1 has to be used because although in a competitive market, demand would be at Q_3, in a market with market power, Q_1 is the observable level of demand.

The competition benefits of the next best alternative to the interconnector then need to be determined to enable an appropriate comparison between the options.

The next sections describe how the various points can be modelled in a rigorous fashion.

3. Measuring market power

To determine the pro-competitive effects of a transmission augmentation it is necessary to determine the effect of the investment of generator market power in both the importing and exporting market simultaneously. There are various methods available for testing for market power in an electricity market, *including* expert opinion, measures of producer concentration in a particular industry, and game theoretic methods.

3.1. Expert opinion

The effect of generator market power on pool prices is commonly modelled by assuming a certain structure of generator bids that reflect the analysts' belief (often based on historical patterns alone) of the extent of generator market power.

This approach is not systematic and is subject to a considerable level of judgement. The unreliability of this approach is best demonstrated by the financial losses incurred by investors in Victoria who relied on these expert opinions.

The proven unreliability and value laden basis of this approach means that any modelling results can be easily undermined and therefore cannot provide a basis for regulatory decision making. There is nothing to recommend this approach.

3.2. Market concentration measures

The alternative to 'expert opinion' is to use one of the various forms of industry concentration ratios such as the standard Herfindahl-Hirschman Index (the so-called HHI test).

Unfortunately these measures of market power provide a relatively poor indicator of market power and are next to useless in the context of a power market. Unlike other markets, electricity demand and supply need to be matched continuously and instantaneously and supply cannot be stored (at least economically). This means that enough capacity has to built to meet a peak demand, which may last for only a few hours a year. The implication of this is that for a large proportion of the time there is a significant amount of idle generation capacity. At these times competition between generators to dispatch their plant could be fierce, even though there are only a few large generators competing (which would normally show up as uncompetitive under the HHI test).

Another feature of the electricity industry that is important in assessing market power is the fact that there are limited substitutes, and in the short term demand is relatively unresponsive to price changes. This means that at times when capacity is scarce, even a system with many small generators (which would generally satisfy the HHI test) can be characterised by high levels of market power.

Thus, the HHI measure is an unreliable measure of market power in the context of a power market (and most markets for that matter). However, even if these types of measures did present a relatively accurate measure of generator market power, it is unclear how a change in the measure of market concentration following interconnection can be translated into an expected price and therefore gross market benefit measure. Therefore the challenge is to develop a measure of market power that takes account of the supply-demand conditions of the market under all relevant circumstances, that can use the NEM rules to determine the influence of greater competition on bidding behaviour and for this information to be translated into an expected price effect in a systematic manner.

3.3. Game theory

Game theory is a branch of mathematical analysis which is specifically designed to examine decision making when the actions of one decision maker (player) effects the outcomes of another player, which may then elicit a competitive response that alters the outcome for the first decision maker.

Game theory provides a mathematical and, therefore, systematic process for selecting an optimal or best strategy given that a rival has their own strategy and preferred position.

Unlike more traditional theories of firm behaviour, game theory considers market outcomes where the behaviour of firms is both rational and interdependent. As stated by Borenstein, Bushnell and Knittel:

> "In a Cournot-Nash equilibrium, each firm considers the output of all the other firms and sets its own output in a way that maximizes its profits when selling to a price-responsive demand curve. In equilibrium, each firm is producing at its profit-maximizing output, given the output of all the other firms."[7]

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[7] Borenstein, S., J. Bushnell and C. Knittel, "A Cournot-Nash Equilibrium Analysis of the New Jersey Electricity Market", University of California Energy Institute, November 1997: http://www.ucei.berkeley.edu/ucei/PDF/sb_jersey.pdf

In short, game theory is the study of multi-person decision problems and is ideally suited where the market is neither perfectly competitive nor monopolistic.[8] Cournot-Nash equilibrium is a solution concept used in game theory that has wide acceptance among economists. In a Cournot-Nash game, no person can improve his or her position by unilaterally changing his or her behaviour. In this sense, if agents are rational and take account of other parties' conduct in choosing their own conduct, one would expect to see behaviour in accordance with what is predicted by a Cournot-Nash equilibrium.

For this reason, the use of Cournot-Nash equilibrium is often implicit in business and regulatory decisions involving actual or potential oligopolies. However, in an electricity market such as the NEM, it is necessary to use the Cournot-Nash equilibrium concept more explicitly, due to the complexity and number of available strategies and possible outcomes. Whilst pointing out its shortcomings, Steven Stoft states that the Cournot model "is probably the best available model" for predicting market power in electricity markets.[9]

Frontier Economics has used this central idea of Cournot-Nash equilibrium to develop bidding strategies for key generators in NEM market modelling. Frontier's NEM model, SPARK, is a NEM dispatch model that is capable of determining equilibrium bids under realistic NEM conditions.

The basic concepts that underpin game theory include:

- **Players**: players are generators who are able to make decisions based on the behaviour they know or expect from other players. Strategic players are given a range of different strategies allowing them to respond to changes in the behaviour of other players. Non-strategic players have a fixed strategy and hence are unresponsive to the behaviour of other players;

- **Payoffs**: in every game, players seek to maximise pay-off (i.e., profit) for a given set of competitor strategies; and

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[8] Gibbons, R., *A primer in game theory*, 1992, Harvester Wheatsheaf, page xi.

[9] Stoft, S., *Power system economics, Designing markets for electricity*, 2002, IEEE Press, page 361. According to Stoft, the key shortcoming with Cournot model is that most competition in a power market is some form of supply-curve competition rather than pure Cournot competition. However, SPARK uses Cournot bidding for strategic players.

- **Equilibrium:** an equilibrium describes a best or optimal set of choices by the players in the game. An equilibrium is an optimum in the sense that if any player makes another choice to improve their own position, this will elicit a strategic response by the other players in a way that will ultimately push the players back to the equilibrium point. This concept of an equilibrium was refined by a mathematician named John Nash. As such it is often referred to as a Nash Equilibrium.

3.3.1. A standard game theory example: Prisoners' Dilemma

To explain the intuition underpinning game theory consider the following classic example – the "Prisoner's Dilemma":

> *Two offenders, A and B, are arrested on the suspicion of committing a serious crime. The authorities also have evidence of involvement in a lesser crime by both offenders. A and B are placed in separate rooms, and the same options given to each:*
>
> *a) if both confess to the serious crime, each receives 8 years in jail*
>
> *b) if both deny the serious crime, each receive 1 year in jail for the lesser crime*
>
> *c) if A confesses and B denies the serious crime, A walks free while B receives 10 years in jail (and vice-versa)*

We assume that A and B have no interest in the jail term given to their partner, and are only concerned about minimising the time they themselves spend in jail. A *payoff* matrix can be constructed showing the available decisions (or *actions*) available to each player and their corresponding jail terms (see Table 1).

Table 1: Prisoners' Dilemma

Prisoner's Dilemma		B	
		confess	deny
A	confess	**A** = -8 **B** = -8	**A** = 0 B = -10
	deny	A = -10 **B** = 0	A = -1 B = -1

It can be seen in Table 1 that no matter what A thinks B may do, A is always better off by confessing. If A thinks B will confess, A chooses to confess and get 8 years rather than deny and get 10 years in jail. If A thinks B will deny, A again chooses to confess and get off free rather than deny and go to jail for 1 year. Similarly, B is always better off by confessing also, hence the equilibrium outcome of this game is for both players to confess and receive 8 years jail. Obviously, both players would be better off if they both denied the serious crime, receiving only 1 year in jail each, hence the dilemma. Adopting a strategy of denying the serious crime and hoping the other player denies also is risky, the other player always has the incentive to confess and get off free, while the denier receives 10 years in jail.

3.3.2. Game theory in the NEM

The same equilibrium principles that have been applied to assess the equilibrium outcome of the Prisoners' Dilemma can be applied to behaviour of independent participants in the NEM.

Generators bid to maximise operating profit; that is, the pool price minus the variable costs of production (which mostly comprises fuel costs). A generator's best bidding strategy is then the bid that results in the highest operating profit having regard to the response of competitors.

An equilibrium set of bids is determined for varying levels of demand from off-peak through to the peak. The equilibrium bids are then used to determine the pool price for each trading interval for each year (as distinct from guessing the bids that generators with market power may submit). The average (time weighted) annual pool price may then be calculated for each year by weighting the outcomes according to the expected hours per year for that demand level.

This approach is more systematic than the expert opinion approach. It does not suffer the problems of industry concentration measures in that it takes account of the actual market conditions of the NEM and the effect on price can be determined, and while modelling assumptions can be made, these are less value driven and more systematic than other approaches and, therefore, the results more defensible.

4. A worked example

4.1. Methodology

This section provides a worked one-year example of the application of game theory to modelling the behaviour of generators in the NEM. Using game theory helps determine how market outcomes would change following a new transmission augmentation and consequently, what market benefits might arise from the attenuation of market power and consequent lower prices.

The base case for analysing the competition effects of the augmentation is a marginal cost modelling run with and without the augmentation. This provides the savings in costs of dispatch brought about by the augmentation, in accordance with the measurement of net market benefits current Regulatory Test.

The next step is to work out how actual prices might be affected by the augmentation. To determine this, the modelling approach assumes that particular generating portfolios are capable of adjusting their strategies by offering lower levels of capacity into the market. The two largest portfolios either side of the proposed interconnection were given the greatest scope to exercise market power. Smaller portfolios throughout the NEM were allowed limited strategies or assumed to refrain from offering a small amount of capacity.

The market outcome was found as a Nash equilibrium in portfolio strategies. Where more than one equilibrium existed, the average outcome (in terms of prices, interconnect flows and so on) was taken. The analysis was conducted over a full year broken up into 10 demand bands. The bands were weighted towards the higher demand periods to give better resolution in the results during these times.

SPARK was used to determine the equilibrium strategies and market outcome in this base case. Care must be taken when introducing the augmentation, since using SPARK to run over the same demand points as the base case will ignore any demand response and overstate the equilibrium price change. Subsequently the upgrade is modelled taking into consideration the long run elasticity of demand.

The benefit of the interconnection from the base case was measured according to the increase/fall in demand and fall/increase in price across regions in the NEM.

SPARK has been very successful in accurately predicting NEM pricing.

The following sections provide the assumptions and results of a Nash Equilibrium NEM modelling process for a 400 MW interconnector between the Snowy and Victorian regions of the NEM.

4.2. Assumptions

The proposed interconnector is a 400 MW augmentation of the existing Snowy-Victoria interconnector. In this regard, it is akin to an analysis of the price and demand impacts of SnoVic 400.

The generators assumed to be strategic bidders are:

Table 2: Strategic bidding assumptions

Player	Stations	Bids
MacGen	Bayswater, Liddell	70% - 100% (in 2.5% increments)
Loy Yang A	Loy Yang A	80% - 100% (in 2.5% increments)

In this example generators have been given capacity withdrawal strategies. It is assumed that the largest generator portfolio either side of the interconnection will have the greatest scope to act strategically. Subsequently Loy Yang A and MacGen have both been given large strategy sets with the ability to withdraw capacity in 2.5% increments

The demand points were forecast for the financial year 2003/2004 in each region of the NEM. Periods were ordered according to their level of Victorian demand. Bands were divided across the year to give greater resolution during periods of high Victorian demand and weighted according to the expected frequency of occurrence in hours per year.

Contracts were assumed to be zero.

4.3. Results

The modelling results are summarised as follows.

The first step is to work out the savings in costs of dispatch brought about by the augmentation. These costs fall by approximately $9.5 million, from $1,753 million to $1,743 million for the year. This represents the area CDO in Figure 1. As discussed, this represents the gross market benefit of variable cost savings as measured by the existing Regulatory Test.

The next step is to work out the 'competition benefits' of the augmentation. Table 3 shows the impact of the upgrade on NEM prices. Table 4 shows the effect on demand in each region.

These results represent the average of the Nash equilibria (where there were more than one for a particular demand point). The average annual prices were calculated by weighting equilibrium outcomes by the expected frequency of occurrence over the year.

Table 3: Annual price change due to upgrade

Region	Price without upgrade	Price with upgrade	Relative change
NSW	$23.24	$25.19	+8.4%
QLD	$15.76	$15.70	-0.4%
SA	$34.52	$32.65	-5.4%
VIC	$29.75	$27.02	-9.2%

Table 4: Average demand change due to price change

Region	Average demand without upgrade (MW)	Average demand with upgrade (MW)	Change[1] (MW)
NSW	8,434	8,349	-85
QLD	5,477	5,526	+49
SA	1,566	1,592	+26
VIC	5,597	5,755	+158

1. The demand changes are based on the following price elasticity of demand assumptions: NSW –0.37, VIC -.38, QLD –0.29, SA –0.32.

The results show that the average annual price paid for electricity following the upgrade fell by over 9% in VIC and over 5% in SA, was practically unchanged in QLD and rose by over 8% in NSW.

On the basis of these results, the total (gross) market benefit of the augmentation is $40.5 million. Gross market benefit rises from approximately

$16,621 million to approximately $16,661 million.[10] This represents the area BEFOC. Subtracting $9.5 million from this figure gives $31 million as the (gross) market benefits from competition combined with an appropriate demand response.

It would also be necessary to calculate the total benefits of the alternative options to the augmentation in order to determine the total net benefit of the augmentation.

[10] Market benefit is based on a long-run consumer willingness to pay of $100/MWh (this assumption is arbitrary and excludes the elastic part of the demand curve). The willingness to pay assumption only affects the magnitude of the calculated benefits for each case, but not the net benefit increase due to the upgrade.