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Solving the Riddle of Combinatorial Logic

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Abstract

Open access to the rail network has been operational in NSW since 1 July 1996. In the NSW framework, pricing is regulated according to the so-called 'combinatorial stand-alone cost test' which is embodied in the NSW Rail Access Regime. This test prevents the infrastructure owner from extracting monopoly rents on captive traffics. The Rail Access Corporation has drawn on economic theory and empirical work to develop a system of pricing tools which provide compact, robust solutions to combinatorial pricing problems which have the potential to be extremely complex. These tools assist in access price negotiations and provide the ability to respond effectively to regulatory questions. This paper explains the theoretical and empirical underpinnings of this ground-breaking approach to monopoly pricing issues—believed to be unique in Australia and probably the World—and recounts some of the practical experiences to date in applying it in both customer negotiations and in the regulatory arena.

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The challenge

Vertical separation of railways is new to Australia. The idea of having separate organisations operating trains and maintaining tracks is a radical shift from the traditional method of organising railways—'vertical integration'—where one organisation does everything. Separate 'above-rail' and 'below-rail' managers have been operating in parts of Europe, notably Britain and Sweden, since the late 1980s, but elsewhere vertical integration remains the rule. True vertical separation in Australia dates back only as far as 1 July 1996 in NSW. An embedded open access unit was trialled within the Australian National Railways the prior year, while that organisation was still vertically integrated

One of the principal business problems to be solved in vertical separation is the establishment of access prices. That is the price which the train operator must pay to use the tracks. Increasingly this problem must be tackled even in vertically integrated systems when third party train operators seek access to the host railway's infrastructure.

Much has been written about the economic theory underpinning access pricing. Freebairn (1998) contains an interesting summary, incorporating Australian experience and data post-Hilmer (Hilmer 1993). Theory focuses frequently on the problem of how to prevent the track owner from abusing market power. This issue is often associated with the separate problem of how to prevent a vertically integrated host railway from inhibiting competition from 3rd party train operators by offering 3rd parties access on onerous terms, or refusing to provide it

In NSW the regulatory framework in which the track owner operates is the NSW Rail Access Regime [henceforth 'The Regime']. This document is established under NSW State Legislation (Transport Administration Act 1996). It is being considered for certification by the National Competition Council as an effective State-based regime, under the Commonwealth Government's 1995 Competition Policy Reform Act.

The Regime has established an unusual system for curbing monopoly price setting. Although it has some parallels to the price regulation method employed by the British Office of the Rail Regulator, and the basic regulatory concepts echo those used by the Interstate Commerce Commission in the United States, it is to my knowledge unique in the World.

Under this system, access revenues must meet both an upper bound and a lower bound test, referred to as the 'ceiling' and the 'floor' respectively. These tests do not apply only to access revenues in total or on average. The ceiling test must be met separately for every possible combination of train movements. (The floor test must also be met for every possible combination of line sections). It is this feature, the so-called 'combinatorial stand-alone ceiling' test, which makes The Regime unique.

One does not need to possess a PhD in mathematics to realise that, on a network of any size, every possible combination of train movements represents a colossal number of combinations. The challenge, for both regulator and monopolist alike, is to make this system work in a way which is transparent and credible to the customers.

Economic theory behind the Regime

The Regime draws its concepts from the writings of the American economist William J. Baumol (Baumol and Sidak 1994). Even though the subject of that book was telecommunication, most of the examples given were railway cases. Indeed Professor Baumol has had a long and comprehensive involvement in railway price regulation over much of his career. The key ideas are summarised below:

- Marginal cost pricing is a recipe for bankruptcy when a firm's production process is subject to economies of scale (Baumol and Sidak 1994 p 34)
- Ramsey pricing (permitting prices to deviate from marginal cost in proportion to the inverse of each product's demand elasticity) minimises the efficiency loss imposed by permitting the firm to increase its overall revenue sufficiently to meet its fixed costs. *[This is the rationale for a negotiate and arbitrate style of access regime.]*
- Perfectly contestable markets permit the firm to earn no more profit than it can obtain in a perfectly competitive market (Baumol and Sidak 1994 p 43).
- The regulatory cost floor must be the higher of marginal cost or average incremental cost (Baumol and Sidak 1994 p 67) *[This is the rationale for having two parts to the floor test.]*
- "The combinatorial test asserts ... that the resulting revenue of every product by itself, and the combined revenue of every combination of the firm's products, must at least equal the corresponding average-incremental cost." (Baumol and Sidak 1994 p 70) *[This is the combinatorial second "limb" of the floor test.]*
- "The analysis underlying the combinatorial cost tests again emphasises that [full cost] allocations are impossible except by unavoidably arbitrary criteria, so that the results are inevitably without economic meaning. More important, the analysis shows that such allocation is unnecessary to prevent cross-subsidy, and that the combinatorial cost test can do the job satisfactorily" (Baumol and Sidak 1994 p 70). *[This is the rationale for a combinatorial ceiling and floor test as opposed to some type of fully distributed cost approach.]*
- "To summarize, the combinatorial stand-alone price ceiling means that the prices of every combination of the firm's products must yield combined revenues not exceeding the corresponding stand-alone cost of the combination of products in question" (Baumol and Sidak 1994 p 78). *[This is the combinatorial ceiling test.]*

The controversial Efficient Component Pricing rule, which has been invoked in other famous regulatory cases such as Telecom NZ vs Clear Communications, is not relied on in the Regime, thanks to vertical separation.

Is the combinatorial test computationally tractable?

Many observers have taken fright at the potential complexity of the combinatorial stand alone cost test. The NSW Minerals Council, representing the coal mining industry—a critical railway customer group—commented in April 1997 that:

> *"the data and computational demands of this approach are so great that it is impossible to faithfully implement"* (NSW Minerals Council 1997 p 69).

After a familiarisation phase, a more considered viewpoint began to emerge. For example, Dr David Cousins, reporting on behalf of the National Competition Council in September 1997 commented that:

> *"The magnitude of the NSW rail network means it will be impossible to ever apply the combinatorial floor and ceiling tests completely. We are inclined to the view, however, that this does not mean that the principles will fail to deliver efficient outcomes. It is apparent that not all combinations need to be calculated – particularly between line sections that are non-contiguous or do not share common facilities"* (Cousins 1997 pp 49-50).

The Minerals Council's own economic experts eventually adopted a more sophisticated type of objection to the combinatorial test. Mr John Daley of AciL economics commented as follows in a critique submitted by the Minerals Council to a review of The Regime by the NSW Independent Pricing and Regulatory Tribunal.

> *"In the Hunter, our model identifies 26 users. 67 million equations need to be specified to define the floor and ceiling price for each user. This is not a trivial computation, even for a regulator with a mainframe.*
>
> *"The interesting thing is that RAC does not intend to compute all the combinations. That is not because of a shortage of computing power but, much more importantly, because of a shortage of key information – notably as to the costs of establishing and operating the rail infrastructure for a combination of users somewhat different from that which currently exists.*
>
> *"If RAC takes a 'short-cut', and tests a limited set of combinations, it would be possible to prove that a particular set of prices contains prices which are too high or too low, but it is not valid to conclude that prices within the floor and ceiling range so calculated are not actually in breach of the floor and ceiling rules. This is because some other combination (not included in the limited test) could allow the price range to be narrowed much further.*
>
> *"RAC evidently believes it can identify a limited number of combinations of users adequate to validly test whether prices comply with the rules. Frankly, it is difficult to conceive how a legal access regime could rely on such intuition"* (Daley 1998 pp 9-10).

Professor Baumol has also commented on the computational tractability issue:

> *"As we noted earlier, full execution of the combinatorial requirement of the stand-alone cost ceiling can be a mind-boggling task that threatens to make the entire procedure impractical. But experience in railroad regulation has shown that such calculations are feasible, and the determination of such cost figures has become a fairly routine activity, with firms specialising in the requisite calculations"* (Baumol and Sidak 1994 p 80)

Why bother?

Accepting the tractability of the combinatorial test, one must surely be tempted to ask why bother going to the trouble of implementing a regulatory system which is so complex?

The answer is given by Mr Daley later in the same paper which was quoted above. The main thrust of that paper was to examine quantitatively the relative efficiency gains or losses to the Hunter Valley coal industry by applying 'Ramsey pricing' (which Mr Daley equates to the RAC approach of negotiating prices subject to a combinatorial ceiling test) versus Fully Distributed Cost pricing (FDC), which is a much simpler, more traditional method of pricing rail services.

> *"You can see from the charts at the right that the 1-part Ramsey (which we've used as the best possible outcome under discriminatory pricing) does produce more tonnes, and does result in the lowest efficiency loss (of the three shown). It also has a more moderate range of access charges than under FDC pricing, as you would expect"* (Daley 1998 pp 18).

> *"What I'd like you to focus on are the three central figures on the right : the efficiency loss for the base case of $4.15 million, for the discriminatory pricing (Ramsey) case of $1.78 million, and for FDC pricing of $9.44 million.*

> *"The superiority of Ramsey pricing on this ground is not disputed. What is at issue is whether it can, in fact, be realised and, assuming it can, whether it is worth it."* (Daley 1998 pp 19).

I believe that the tractability of the combinatorial test has been demonstrated by the tools which the Rail Access Corporation has developed to implement the requirements of The Regime. These will be explained in their practical and theoretical context below. From what has been said above, even by The Regime's detractors, the resolution of this technical challenge clearly has the potentially to provide great rewards.

The response

Practical issues to be overcome

The combinatorial ceiling test is a test which is applied to a given set of access prices to determine whether that price set is acceptable. The procedure described below is a procedure for testing a price set, not for generating it. Space does not permit a full exposition of the method of generating prices which are likely to meet the combinatorial ceiling test, although such analytic methods do exist and have been of great assistance to the Rail Access Corporation's coal price negotiations over the past few years

To perform the combinatorial ceiling test, one must compare revenues, which are customer based, to costs, which are track section based. The first practical issue to be overcome is the fact that customers and track sections don't match exactly. It isn't possible to calculate an access profit separately for each customer because, although the revenue derived from that customer is well defined, the costs of providing access are common across a group of customers. Allocation of common costs among customers is always subjective.

Attempting the profit calculation on a track section basis instead does not eliminate the problem. While the costs and asset valuations are well defined for sections of track, estimating the applicable revenue would involve an apportionment of access charges from many disparate journeys to each of the track sections involved in those journeys. Apportionment of this kind is always subjective. This mismatch presents a conceptual stumbling block for many, but it is this very fact which makes the combinatorial approach work well.

A concrete example may assist in explaining the issues. Figure 1 is a schematic diagram of an artificial rail system similar to the Hunter Valley coal network. Coal is transported to a single port from five mines: Anthracite, Bituminous, Cambrian, Devonian, and Exothermal (A,B,C,D, and E). The railway network serving these mines consists of six line sectors numbered 901 – 906.

Recognising the fundamentally different bases of revenue and cost is the first step to resolving the problem. Separate tables are required for revenue and cost. The revenue table must be customer-oriented. That is each mine in the Hunter Valley coal system will have its own annual tonnage figure, its own access price, and consequently its own annual access revenue payment to RAC.

The fixed cost table must be track section-oriented. Each track section (we use the terminology 'line sector' or 'sector') has its own identifying numerical code ('sector code'). Sectors are generally the arcs (sections of plain track, possibly being either single or double track) connecting nodes (or rail junctions) in the network. Each sector has its own characteristic fixed (recurrent infrastructure maintenance and renewal) cost, to which is added that sector's allocated proportion of indirect costs (network-wide common costs such as train control and access business overheads). Each sector also has its own asset value, annual depreciation charge, and finally a characteristic variable cost rate, expressed as dollars per thousand gross tonne kilometres (GTK).

Figure 1.

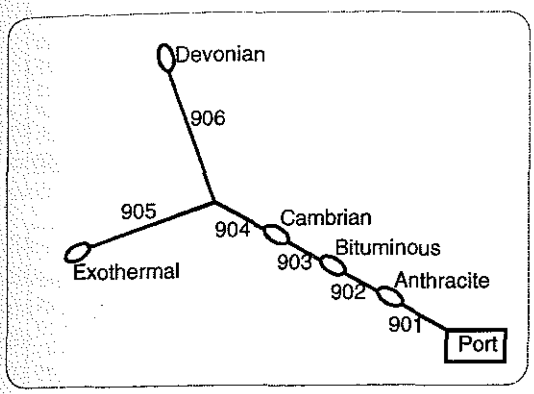

Table 1

Revenue Table					
	Category I			Category II	
Mine	**A**	**B**	**C**	**D**	**E**
Tonnes/yr (M)	10	13	11	3	6
Access Price ($/tonne)	0.80	0.85	0.87	1.40	1.70
Revenue/yr ($M)	8.00	11.05	9.57	4.20	10.20

Table 2

Cost Table -- non-variable costs							
Sector	**901**	**902**	**903**	**904**	**905**	**906**	*($M/km)*
Length (track km)	70	15	7	40	100	45	
Fixed cost/yr ($M)	2 80	0.60	0.28	1 60	4 00	1.80	*0.040*
Share of indirect costs/yr ($M)	0.35	0.08	0.04	0.20	0 50	0 23	*0.005*
Depreciation/yr ($M)	0.70	0.15	0.07	0.40	1 00	0 45	*0.010*
Asset value ($M)	49 00	10 50	4 90	28 00	70 00	31 50	*0.700*
Maximum permitted ROA/yr ($M)	3.14	0.67	0.31	1.79	4.48	2.02	*6.4%*
Total non-variable costs/yr ($M)	6.99	1.50	0.70	3.99	9.98	4.49	

Variable Cost Table						
Sector	**901**	**902**	**903**	**904**	**905**	**906**
Variable cost rate ($/'000 gtk)	3.10	2.90	2.40	2.70	3.30	2.50

Separate identification of variable costs is important to avoid complications. Each mine also has a characteristic variable cost figure, which can be derived from data previously described and expressed in dollars per net tonne of coal shipped. This customer-specific variable cost is calculated in three steps. First the mine tonnage is multiplied by the typical gross to net ratio (usually about 1.8 for block coal trains returning empty) and then by the length of each sector to get the GTK's traversed on that sector on behalf of that mine. This GTK figure is then multiplied by the variable cost rate for that sector to obtain the variable cost in dollars for that mine on that sector. Finally, summing over the sectors actually used by that mine, one gets the variable cost in dollars per year.

Table 3

gtk Table (Mgtk/yr)	gross to net ratio =		1.8				
Mine Sector	901	902	903	904	905	906	Sum of sectors
A	1 260	-	-	-	-	-	1 260
B	1 638	351	-	-	-	-	1 989
C	1 386	297	139	-	-	-	1 822
D	378	81	38	216	-	243	956
E	756	162	76	432	1,080	-	2 506
Sum of mines	5,418	891	252	648	1,080	243	8,532

Mine-Variable Cost Table	($M/yr)						
Mine Sector	901	902	903	904	905	906	Sum of sectors
A	3.91	-	-	-	-	-	3 91
B	5.08	1 02	-	-	-	-	6 10
C	4.30	0 86	0 33	-	-	-	5.49
D	1.17	0 23	0 09	0 58	-	0.61	2 69
E	2.34	0.47	0.18	1.17	3.56	-	7.73
Sum of mines	16.80	2.58	0.60	1.75	3.56	0.61	25.91

Table 4

Revenue Net of Variable Cost Table ($M/yr)

Mine	A	B	C	D	E
Revenue/yr ($M)	8 00	11 05	9.57	4 20	10.20
Variable cost/yr ($M)	3.91	6.10	5.49	2.69	7.73
Net revenue/yr ($M)	4.09	4.95	4.08	1.51	2.47

An intermediate table of net revenue by mine must be constructed. For each mine this value is access revenue (to RAC, cost to the mine) less variable cost in dollars for the mine, as calculated above. Having established a net revenue table and a non-variable cost table, it is possible to perform a single combinatorial ceiling test. The method is as follows:

1. Identify one set (or combination) of mines which will be ceiling tested.
2. From the net revenue table, sum across all mines in the combination.
3. Identify which line sectors must be used to convey coal to port from each mine.
4. Compile a superset of the sectors identified in the step above for the mines in the combination. The superset is complete once it is established that every sector in it is necessary to convey coal to port from the mines in the combination.
5. From the non-variable cost table, sum the fixed cost, the allocated share of non-sector-specific cost, the depreciation, and the maximum permitted return (the NSW Rail Access Regime specifies a maximum permitted rate of return, which is currently 8.0% real pre-tax. This rate is multiplied by the sector's asset value to obtain the maximum permitted return in dollars per year for the sector) for all sectors in the superset identified above.

6 The net revenue is compared to the sum of non-variable costs including the maximum permitted return. The latter is the stand alone cost of serving the combination of mines. If the net revenue exceeds the stand alone cost then the ceiling is violated. Otherwise, the ceiling test is met.

At this stage one may be wondering how such a laborious procedure could possibly be carried out a large number of times in an efficient manner. Fortunately, the standard tools of matrix algebra are well suited to this challenge

Step 3 above requires only a table which makes the correspondence between mines and line sectors explicit We call this the "Mine-Sector Correspondence Table". It contains only ones and zeros. There is one row for each mine, and one column for each sector in the system. A cell contains a one if that column's sector is required by that row's mine to convey coal to port, and a zero otherwise.

Table 5

Mine-Sector Correspondence Table

Mine \ Sector	901	902	903	904	905	906
A	1	0	0	0	0	0
B	1	1	0	0	0	0
C	1	1	1	0	0	0
D	1	1	1	1	0	1
E	1	1	1	1	1	0

A vector can be constructed also of ones and zeros which has ones only in the positions corresponding to mines which are in the combination being tested. When this vector is matrix multiplied with the Mine-Sector Correspondence Table, the resulting vector is the superset of line sectors required to serve that combination of mines; a vector of ones and zeros, with ones only in the positions corresponding to sectors which are required to serve the combination of mines. This is sufficient to perform step 4 above.

Having established these tables, it is now possible to describe the automatic procedure for testing any number of combinations with a single series of matrix multiplications of the net revenue, non-variable cost, and Mine-Sector Correspondence Tables.

A set of combinations must be chosen manually. These are recorded in a table which has one row for each combination, and one column for each mine. With approximately 30 mines, the number of conceivable combinations for the Hunter Valley is enormous, but practically speaking a very small set would ever need to be tested Once that set is selected, the table can be completed. The cells in this table would contain only ones and zeros—a one if the row's combination contained the column's mine.

Table 6 below has been constructed by selecting the combinations which are the most 'obvious' from the perspective of combinatorial testing Each of the first five combinations contain only one mine. These combinations permit testing each individual mine on a stand-alone basis. The combination matrix for these five is a diagonal matrix.

The sixth combination in table 6 is the combination of all mines. Clearly this combination must always be tested, although it is not always the one which places the greatest constraint on pricing.

Combination 7 is the combination of all mines between the port and the second-closest mine. It contains only mines A and B. Combination 8 is the combination of all mines between the port and the third-closest mine. It contains only mines A, B, and C. Combination 9 is the combination of all mines except mine E. It contains A, B, C, and D. Following the same pattern, combination 10 contains all mines except mine D. It contains A, B, C, and E.

Experience with combinatorial testing has shown that combinations of the type represented by combinations 7 - 10 are the most likely to cause a ceiling violation if pricing is too high.

The final combination, containing mines A, C, and E only was chosen to illustrate the point that combinations with little common use of track are seldom important.

Table 6

Combinations						
	Mine	**A**	**B**	**C**	**D**	**E**
Combination						
1	A only	1	0	0	0	0
2	B only	0	1	0	0	0
3	C only	0	0	1	0	0
4	D only	0	0	0	1	0
5	E only	0	0	0	0	1
6	All mines	1	1	1	1	1
7	Port to B	1	1	0	0	0
8	Port to C	1	1	1	0	0
9	Port to D	1	1	1	1	0
10	Port to E	1	1	1	0	1
11	A, C and E only	1	0	1	0	1

Matrix multiplication of this combination table by the net revenue vector (last row in Table 4) yields a vector of total net revenue for each combination. That vector sits in the first data column in the Combinatorial Ceiling Test Table (Table 8).

Matrix multiplication of the combination table by the Mine-Sector Correspondence Table yields a matrix which has one row per combination and one column per sector. This table contains a one if the column's sector is required to convey coal to port from any of the mines in the combination, and a zero otherwise. We call this the Combination-Sector Correspondence Table.

Table 7

Combination-Sector Correspondence Table

Combination	Sector	901	902	903	904	905	906
1	A only	1	0	0	0	0	0
2	B only	1	1	0	0	0	0
3	C only	1	1	1	0	0	0
4	D only	1	1	1	1	0	1
5	E only	1	1	1	1	1	0
6	All mines	1	1	1	1	1	1
7	Port to B	1	1	0	0	0	0
8	Port to C	1	1	1	0	0	0
9	Port to D	1	1	1	1	0	1
10	Port to E	1	1	1	1	1	0
11	A, C and E only	1	1	1	1	1	0

Matrix multiplication of the Combination-Sector Correspondence Table by the total non-variable cost vector (the total row from Table 2), yields a vector of total non-variable cost including permitted return for each combination (stand alone cost). That vector sits in the second data column in the Combinatorial Ceiling Test Table.

Finally, the total net revenue per combination vector is subtracted from the total non-variable cost including return by combination vector (in Table 8 the second data column is subtracted from the first), and if any cell contains a positive number the ceiling test has been failed. The maximum amount by which net revenue exceeds stand alone costs for any combination is the monopoly rent. Normally prices would need to be adjusted downward for mines in this combination. In the example given, the combination of mines from the Port to the Cambrian mine (mines A+B+C) is the limiting combination and the surplus profit earned on this combination is the monopoly rent.

Table 8

Combinatorial Ceiling Test

		($M/yr) Excluding variable costs			
Combination		Net revenue	'stand-alone' costs	Surplus profit ($M)	Monopoly rent
1	A only	4 09	6 99	-2 89	-
2	B only	4.95	8 48	-3.53	-
3	C only	4 08	9 18	-5 10	-
4	D only	1 51	17.66	-16 15	-
5	E only	2.47	23.15	-20.68	-
6	All mines	17.11	27 64	-10 53	-
7	Port to B	9.05	8 48	0 57	0 57
8	Port to C	13.13	9.18	3.95	3.95
9	Port to D	14 64	17 66	-3 02	-
10	Port to E	15 60	23 15	-7 55	-
11	A, C and E only	10.65	23.15	-12.51	-

It is worth noting in passing that while there were 120 possible combinations, only the first 10 really warranted testing. The 11th combination, (mines A+C+E), was included to make the point that when mines are chosen at random and there is little common usage of sectors, there is little likelihood of breaching the ceiling. For this combination the 'slack' between the net revenue and the ceiling is greater than for any of the other combinations tested except the Devonian mine alone and the Exothermal mine alone.

Theoretical issues to be overcome

This highly automated method of conducting simultaneous ceiling tests on many combinations requires only a single net revenue table, a single non-variable cost table, and a single Mine-Sector Correspondence Table, which are all small and easily constructed. It is this compactness which gives the method its simplicity and robustness. The use of matrix algebra greatly reduces the opportunities for calculation errors or formula mistakes as the entire procedure consists of a handful of matrix multiplications

The foregoing discussion of practical issues relies on a number of assumptions. One in particular should be made explicit in order to satisfy theorists that no improper shortcuts are being taken: the decomposability of network costs into independent sector costs.

A vital step in making this combinatorial procedure work efficiently is the construction of a compact cost table. The assumption on which this step relies is this:

> *It is assumed that the non-variable costs incurred on a sector, including capital costs associated with depreciation and a permitted return on assets employed, are independent of the combination of mines which are generating the traffic on each sector.*

Obviously if this assumption did not hold, then each different combination would face a different set of costs on each sector. That would seriously undermine the tractability of the stand alone cost calculation.

Looking at networks generally, it is not always the case that costs on segments of a network are independent of the volume of traffic. Gas and water pipelines, and high voltage transmission lines in particular fail to exhibit this characteristic. This assumption fails to hold for many types of telecommunication infrastructure. That being the case one is justified in asking how things stand for a rail infrastructure network.

Fortunately, railway infrastructure has particular capacity characteristics (as do fibre-optic telecommunications links) which validate this assumption. Increments of capacity can only be added to railway networks in extremely large lumps. The smallest unit of capacity is a single track. There is no lower capacity configuration which can be employed, even on extremely low volume corridors, and a single track (with occasional crossing loops) is sufficient to carry up to several million net tonnes of freight per annum. Once a single track railway with crossing loops is insufficient to carry the volume, a double track railway is required. There is virtually no configuration which is intermediate between these two limits. (Apart from sophisticated signalling arrangements associated with crossing loops which permit trains to run closer together, thus squeezing modest capacity improvements from a given number of tracks).

To a large extent, the non-variable recurrent costs and capital costs are determined by the number of tracks per sector. Therefore, as long as the volume demands placed on the network by different combinations do not differ sufficiently to require changing the track configuration from double to single track or vice versa, the cost table will be virtually independent of the combination chosen.

On the strength of this argument, the vital cost decomposability assumption appears to be valid over a broad range of mine combinations. For those combinations at the fringe it is arguable that they are unlikely to pose a serious risk of ceiling violation for networks configured similarly to the Hunter Valley coal system.

The consequences

What the regulatory bodies made of it

During its process of evaluating whether The Regime was an effective State-based regime, the National Competition Council asked that certain aspects of The Regime be referred to an appropriate independent body to:

- review the definitions of economic terms,
- to determine an appropriate treatment of depreciation and asset valuation, and
- to review the maximum permitted return

The NSW Independent Pricing and Regulatory Tribunal (IPART) was given the task of reviewing these aspects of the Regime. IPART's final report was published on 28 April 1999.

In the course of IPART's investigations, RAC submitted a copy of the combinatorial stand-alone ceiling testing model to IPART for information on a commercial in confidence basis. Essentially that model was identical to the one described in this paper.

Although IPART elected to make no specific commentary on the modelling approach, it is clear that if they had lacked confidence in it they would not have put forward a set of recommendations which rely implicitly on the feasibility of evaluating the ceiling test.

What the customers thought

Negotiations over Hunter Valley coal access prices for the 1997-98 and 1998-99 years were conducted in anticipation of IPART's findings. The unusual character of The Regime's ceiling test prompted RAC to suggest to the customers a volume incentive scheme which was designed specifically to minimise the chance of violating the ceiling test, even if coal tonnages exceeded forecasts significantly.

In common with many volume incentive schemes, this one has a higher unit price for low volumes (the 'pre-cusp' price) and a lower unit price (the 'post-cusp' price) once some volume threshhold (the 'cusp' tonnage) has been surpassed. Each mine has its own 'pre-cusp' price and 'post-cusp'price. The unusual feature of this scheme is that the 'post-cusp' prices for every Category I mine apply from a certain date (the 'cusp day'). The cusp day is the day on which the combined tonnage from all Category I mines for the year first exceeds the cusp tonnage.

Usually, each customer has its own price break point The collective nature of the price break point in this system is what permits pricing to be linked to the ceiling test. The cusp tonnage and pre-cusp prices can be set so that the infrastructure owner recovers the full fixed costs and permitted rate of return by cusp day, and recovers variable costs only past that point. This innovation does indeed assist in minimising the likelihood and the extent of ceiling violations.

At first it was controversial to some degree because miners felt uncomfortable that their competitors received a volume-price break based partly on the tonnages shipped by other mines Nevertheless, I am pleased to report that this scheme has now achieved good acceptance among customers. After the initial operation of this scheme in 1997-98, it was reintroduced, with fine-tuned parameters, for the 1998-99 year with no objections.

More generally The Regime appears to have gained support from the Minerals Council following IPART's final report of 28 April 1999. Mr Denis Porter, Executive Director of the NSW Minerals Council wrote in the Newcastle Herald of 8 May 1999,

> *"The NSW Minerals Council joins The Newcastle Herald in commending the Independent Pricing and Regulatory Tribunal of NSW (IPART) for its report on rail access charges"* (Porter 1999 p 10).

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