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FOREWORD

The sixth Industry Economics Conference was hosted by the Melbourne Business School at the University of Melbourne and was held from 10–11 July, 1997. The theme of the conference was *Making Competitive Markets*. The invited papers presented at the conference and the accompanying discussion are presented in the report of the conference proceedings.

The aim of these conferences is to bring together leading researchers and policy makers in the field of industry economics to discuss their current work, to examine emerging ideas and methodologies, to establish and extend communication channels and to encourage further research. To this end, the 1997 conference features papers from 13 invited speakers and 27 papers contributed by other speakers. The conference organisers were particularly pleased that Professor Paul Milgrom and Professor Frank Wolak of Stanford University and Professor Graciela Chichilnisky of Columbia University were able to present papers at the conference.

The 1997 Industry Economics Conference was partly sponsored by the Industry Commission. The 1998 conference will be hosted by the Australian National University in Canberra.

Thanks are due to the conference hosts and especially the conveners of the conference, Joshua Gans (Melbourne Business School), Charles Hyde (University of Melbourne) and Ilias Mastoris and Don Gunasekera (Industry Commission). These proceedings were prepared by Ilias Mastoris, Antonia Cornwell, and Adam Phillips with assistance from Janet Savvides.

Bill Scales

Chairman, Industry Commission

February 1998

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PANEL SESSION 1

Invited paper 1

Telecommunications following deregulation*

Henry Ergas
Auckland University

* Comments made by Dr Ergas are summarised in the following pages for the readers convenience. They are based on his article, ‘Telecommunications Across the Tasman: A Comparison of Regulatory Approaches and Economic Outcomes in Australia and New Zealand’ in ‘Deregulation of public utilities: current issues and perspectives, edited by Megan Richardson (1996).

The following is a summary of the presentation made by Professor Henry Ergas

In this paper, Professor Ergas reported on comparisons between the reforms of telecommunications regulation in Australia and New Zealand, and on the impacts or outcomes of the reforms in the two countries.

Australia and New Zealand both began the process in the latter part of the 1980s. However they followed very different paths. In New Zealand, the Government immediately pursued a light-handed approach by removing constraints on entry and competition, avoiding industry-specific regulations covering access to the network of the incumbent (Telecom Corporation of New Zealand or TCNZ) by competitors, and privatising TCNZ. In contrast, Australia engaged in a lengthy process of deregulation, beginning with liberalisation of value-added services and customer premises equipment, subsequently licensing one additional fixed network carrier (Optus, which purchased the assets of Aussat from the Government) and two additional mobile carriers, instituting an industry regulator (Austel), and retaining government ownership of the incumbent (later renamed Telstra). Regulatory restrictions acted to protect the fixed network competitor and increase the sale price of Aussat.

A consequence of these different approaches was that Australia developed a more complex regime than New Zealand, involving more pages of legislation and more staff and greater expense in administering and dealing with the regulations.

The effectiveness of the regulatory systems is primarily assessed by examining the outcomes or results of these systems in terms of their impact on the productivity of the telecommunications industry, telecommunications prices, quality of service, social objectives (in particular universal service obligations) and profitability and state of competition of the industry.

Although there are serious measurement difficulties, available evidence suggests that productivity has increased more rapidly and overall consumer prices have decreased more rapidly in New Zealand than in Australia. Prices now appear to be lower in New Zealand, especially for business customers. There has been a greater degree of tariff rebalancing in New Zealand with large increases in residential access rents and very steep falls in long-distance rates. The percentage of all households with a phone is about 96% in both countries, and the penetration of telephones in low-income households in New Zealand has not been significantly affected by the relatively high access rents.

Life has been extremely difficult for the new competitors in New Zealand, not having any assistance from the regulatory regime. In Australia, the duopoly environment in the fixed network (until 1 July 1997), and industry-specific regulation, have given protection to the new competitor. Nevertheless, the market share lost by TCNZ to competitors (principally, Clear Communications) has not been greatly different from the share lost by Telstra to Optus.

It can be argued that market share is not necessarily a good indicator of competitiveness. When evaluating the success of failure of the policy, the issue is not market share but efficiency of the incumbent and the benefits to consumers induced by the state of competition. On this basis the “light-handed” regulation and privatisation policies of New Zealand appear to have been more effective than the “heavy-handed” regulation of the Australian authorities.

PANEL SESSION 1

Invited paper 2

Access pricing in telecommunications

Graeme Woodbridge
Australian Competition and Consumer Commission

2.1 Introduction

Recent amendments to the *Trade Practices Act* 1974 (the Act) have changed the environment within which access to services in the telecommunications industry are determined. One change has been to afford two important functions to the Australian Competition and Consumer Commission. The Commission will have a role in determining:

- the services to which access to third parties must be provided; and
- the terms and conditions upon which access is to be provided.

It must be stressed that the legislation envisages a regime of industry self regulation and commercial determination. A primary mechanism through which services can be 'declared' as access services is through the recommendation of the Telecommunications Access Forum (TAF). Recommendations by the TAF are to be by industry consensus. In addition, it is envisaged that the primary mechanism through which the terms and conditions of access are to be determined is through commercial negotiation.

The Commission does however have important functions in both the declaration of access services and in the determination of terms and conditions of access. During the transition to the new regime the Commission has been required to deem certain services (contained in existing access agreements) to be declared.[1] In the long term the Commission can also declare services after holding a public inquiry.

In regard to the terms and conditions of access, the Commission's role can be described as one of a 'safety net'. One of its main functions is to arbitrate disputes if the terms and conditions of access cannot be determined through commercial negotiation or alternative dispute resolution processes.

The aim of this paper is to outline the Commission's approach to its role in access pricing. This involves an outline of the Commission's on-going responsibilities in this area and a brief discussion of its approach to these responsibilities. It also involves a discussion of a recent determination by the Commission specifying interconnection prices for a certain class of service providers for a six month transitional period. The discussion draws heavily on two Commission publications — *Access pricing principles telecommunications: a draft guide* (28 February 1997) (the draft guide) and *Determination under section 41 of the Telecommunications (Transitional Provisions and Consequential and Amendments) Act 1997* (25 June 1997). The Commission is

[1] For more details see ACCC, *Deeming of Telecommunications Services*, 30 June 1997.

currently refining its approach to access pricing as detailed in the draft guide and will release a revised document during the month of July.

2.2 The Commission's responsibilities in access pricing

Under the recent amendments to the Act, the Commission has both an on-going role and a transitional role in access pricing.

On-going role

Under Part XIC of the Act, the Commission has a role in determining a price for a declared service, or a method for ascertaining a price when undertaking the following tasks:

- approving (or otherwise) the TAF access code which may include the model terms and conditions for access to declared telecommunications services;
- approving (or otherwise) undertakings submitted by access providers which may include the terms and conditions of access to declared telecommunications services; and
- arbitrating disputes between parties concerning the terms and conditions of access to declared telecommunications services.

Transitional role

The legislation also required the Commission to determine transitional terms and conditions upon which a certain class of service providers connect to Telstra's network. In this determination the Commission reduced usage charges service providers using Telstra's National Access service must pay for originating and terminating calls. These terms and conditions, determined under section 41 the *Telecommunications (Transitional Provisions and Consequential Amendments) Act* 1997, will continue for a six month period until 31 December 1997.[2]

2.3 Legislative criteria

The Commission in meeting its on-going and transitional access pricing responsibilities must ensure that access prices are *reasonable*. In determining

2 Or for a longer period as determined by the Commission.

whether terms and conditions are reasonable, Part XIC specifies that regard must be had to the following matters:

- whether the terms and conditions promote the long term interests of end-users of carriage services or of services supplied by means of carriage services;
- the legitimate business interests of the carrier or carriage service provider concerned, and the carrier’s or provider’s investment in facilities used to supply the declared service concerned;
- the interests of persons who have rights to use the declared service concerned;
- the direct costs of providing access to the declared service concerned;
- the operational and technical requirements necessary for the safe and reliable operation of a carriage service, a telecommunications network or a facility;
- the economically efficient operation of a carriage service, a telecommunications network or a facility; and
- the value to a party of extensions, or enhancement of capability, whose cost is borne by someone else.

This does not, by implication, limit the matters to which regard may be had.

The long term interests of end-users are promoted by achieving the following objectives:

- promoting competition in markets for telecommunications services;
- achieving any-to-any connectivity in relation to carriage services that involve communication between end-users; and
- achieving the economically efficient use of, and the economically efficient investment in, telecommunications infrastructure.

The criteria above are interdependent. In some cases promoting one criterion will promote another. In other cases, the criteria are conflicting. For example, telecommunications is an industry where the delivery of many services is characterised by large economies of scale and scope. Therefore, a central dilemma which must be confronted is that an access price that promotes the economically efficient use of infrastructure in the short term may, in some cases, not promote efficient investment in infrastructure in the long term and may not be consistent with the legitimate business interests of the access provider. In particular, an access price based on the direct incremental cost of providing access may not always allow an efficient access provider to recover all its costs.

In addition to promoting the economically efficient use of, and investment in, infrastructure, the access regime established by Part XIC attempts to open up to competition markets which are potentially competitive but where the scope for competition depends on the services of bottleneck facilities.[3] The access price should allow more efficient sources of supply to displace less efficient sources within these potentially competitive markets. However, the access price should also allow vertically-integrated firms to exploit economies of scale and scope to deliver services to end-users at least cost.

Further, access prices and the processes of competition which Part XIC harnesses should encourage suppliers to produce the kinds of services most highly valued by end-users, improve customer choice and product quality, and supply services in the least-cost way.

2.4 Commission's draft approach to access pricing

The Commission's approach to access pricing, as detailed in the draft guide can be divided into four parts:

- identifying declared services to which the Access Pricing Principles (APP) should apply;
- broad pricing principles;
- pricing rules or guides which will assist the Commission in assessing undertakings and in arbitrations; and
- methodology the Commission will apply when required to determine an access price.

Declared services to which the access pricing principles should apply

The range of declared services can be broad, including services required to achieve any-to-any connectivity. As a result it may not be appropriate to apply the APP (in particular cost-based pricing) to all declared services.

In the draft guide the Commission specified pricing principles that it will apply to services that:

---

3 A bottleneck facility is used to provide services that are essential for firms to supply in downstream markets. A bottleneck facility is usually very costly or impossible to duplicate. As such, there is scope for the owner of a bottleneck facility to reap abnormally high profits through restricting the supply of services from the infrastructure and reducing competition in dependent markets.

- are essential for competition in dependent markets;
- have a high degree of bottleneck power; and
- are not highly contestable.[4]

One example, is the Customer Access Network (CAN) which has a high degree of bottleneck power and is considered to be an essential service for competition.

The largest potential gains form regulatory intervention in access pricing are likely to come from cost-based pricing of the above services. Narrowing the range of services also reduces the risk of the loss that may be caused by inappropriate regulation.

Broad pricing principles

An access price consistent with the reasonableness criteria is difficult to determine *ex ante*. In the draft guide the Commission has indicated its approach to access pricing is designed to constrain access providers to price consistent with that would prevail if they faced effective competition. This yields four broad pricing principles.

Access prices should be cost based

Price of an access service should equal the minimum costs an efficient firm would incur in the long run in providing the service. The relevant costs are the economic costs of providing the service.[5] These are the on-going (or forward looking) costs of providing the service, including a normal commercial return on efficient investment.

Access prices should not discriminate in a way which reduces efficient competition

An access provider should not be able to price discriminate to reduce efficient competition in downstream markets. This does not mean an access service need be uniformly priced to all customers. Rather, the Commission envisages that in the usual case undertakings will comprise the same menu of offerings for a

[4] A service that is not highly contestable is one where there are few or no alternative potential sources of supply that could economically displace the current supplier.

[5] If there are short-run capacity constraints prices could rise to ensure that services go to the highest-valued users. However, access prices should not provide incentives for access providers to artificially constrain capacity to earn congestion rents.

service to all customers on a non discriminatory basis.[6] Such a principle is necessary to ensure the access price allows more efficient sources of supply in dependent markets to displace less efficient.

Different prices for a service can occur where there are demonstrated differences in the economic costs of supplying the service to different customers. For example, a firm offering cost-related discounts for bulk volume purchases would be consistent with non discriminatory pricing if the same offer was available to all.[7] Alternatively, an access seeker may commercially negotiate for itself a better access price.

Access prices should not be inflated to reduce competition in dependent markets

A firm facing effective competition will not be able to inflate the access price with the aim of reducing competition in dependent markets.

Access prices should not be predatory

If the forces of competition (or threat of competition) work effectively, a supplier will not be able to successfully predatory price. A predatory price is a price below the incremental cost of production with the aim of reducing competition or discouraging entry into the market (with the objective of pricing above cost once the competition has been removed).

Pricing Guides

In reality it is difficult, time consuming and costly to determine whether a price is cost based, discriminates or is inflated to reduce efficient competition, or is predatory. The Commission has developed price guides that involve comparisons between access prices and observable (or potentially observable) prices and are designed to provide parties with some assistance in developing undertakings. If a price in an undertaking is inconsistent with the guides, it will signal to the Commission that it may be inconsistent with the pricing principles and the legislative criteria under Part XIC, and will need to be examined

[6] For example, an access provider could offer access seekers a menu of multi-part pricing schemes for a service. Alternatively, different price/quality offerings could be made. For example, lower prices could be offered for a lower quality service. This would allow different customers to adopt different pricing plans in accordance with their own requirements.

[7] Cost differences arising from supplying customers in different locations or with different credit worthiness may also, among other things, potentially provide grounds for charging different customers different prices.

carefully. These guides may also be used by the Commission in arbitrations to assist in narrowing the range of acceptable price outcomes.

1. Access prices available to competitors must not be greater than the access provider's best price to its own vertically-integrated operations (unless cost justification is provided).
2. Any part of a service, if declared, should be priced at less than the price of the whole service (unless cost justification is provided).
3. An access price for a service must not be greater than the sum of the access prices for the parts of the service (unless cost justification is provided).
4. Any increase in an access price must be based on recognisable changes in the cost of providing the service.
5. Access prices should be based on the functionally of the service — all access prices giving the same functionality should be priced the same.
6. An access price should not be greater than the retail price of the service.
7. Access prices for unbundled elements of a service must be priced the same across all bundled services.

Methodology for determining a price

When arbitrating disputes on access prices, and where necessary when approving undertakings, the Commission must be satisfied that the access price is based on the cost of providing the service. Determining a cost-based price involves identifying which costs to include and establishing and verifying the size of these costs.

There are many variants of cost-based pricing depending upon the costs that are included, how they are allocated and how they are measured (particularly common costs and capital costs).[8] The Commission's view is that for the types of services mentioned above, the access price should be based on the total service long run incremental cost (TSLRIC) of providing the service.

TSLRIC is the incremental or additional costs the firm incurs in the long term in producing the service, assuming all of its other production activities remain unchanged. It is the cost the firm would avoid in the long term if it ceased to provide the service. As such, TSLRIC represents the costs the firm necessarily

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8 These variants include directly attributable incremental costs (DAIC), fully distributed costs (FDC), short-run incremental costs (SRIC), long-run incremental costs (LRIC), etc.

incurs in producing the service and captures the value of society's resources used in its production.

TSLRIC consists of the operating and maintenance costs the firm incurs in providing the service, as well as a normal commercial return on capital. TSLRIC also includes common costs that are causally related to the access service.

TSLRIC is based on forward-looking costs. These are the on-going costs of providing the service in the future using the most efficient means possible and generally available. In practice this often means basing costs on the best-in-use technology and production practices and valuing inputs using current prices.[9]

Measuring TSLRIC is a difficult and time consuming exercise. Decisions about how to measure and allocate costs can potentially have as large an effect on the access price as the choice of pricing methodology. Details concerning the measurement of costs are included in the draft guide.

2.5 Transitional interconnection price

As indicated above, the Commission was also required under the legislation to make a determination of the terms and conditions a certain class of service providers connect to Telstra's network. These are transitional provisions covering the six month period until 31 December 1997.[10] It is envisaged that this will provide service providers sufficient time to make their own commercial arrangements with Telstra and other carriers.

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9 In most cases, using forward looking rather than historic costs will result in the more efficient use of, and investment in, infrastructure. Historic costs guarantee a normal commercial return to the access provider independent of the quality of its investment decisions. Cost valuation based on the best-in-use technology (rather than historical costs) provides stronger incentives for appropriate investment decisions through rewarding/penalising the access provider for good/poor investment decisions. Using historic costs also increases the scope for access providers to shift costs from competitive segments of the market to less competitive segments. This can deter entry and inhibit competition in dependent telecommunications markets. Finally, efficient 'build or buy' decisions will be based on whether a firm can provide the service at a lower cost using the best-in-use technology. As historic costs may not represent costs using the best-in-use technology, access prices based on these costs may result in inefficient build or buy decisions.

10 Section 41 of the *Telecommunications (Transitional Provisions and Consequential and Amendments) Act* 1997.

The major part of the Commission's determination under section 41 was to review the terms and conditions of Telstra's National Access service. National Access is a national access and egress service for service providers who provide call management services to third parties. It allows service providers with their own switching equipment to connect to Telstra's network and provide end-to-end services over that network.

In the limited time available, the Commission was not able to undertake a full information gathering and verification process that could be expected in an arbitration. As a result, the Commission adopted a pragmatic approach which it considered appropriate given the transitional nature of the determination. The approach involved benchmarking the terms and conditions of National Access to the current Telstra–Optus Access Agreement. Specifically, the Commission benchmarked the terms and conditions of the services provided by Telstra to Optus that use bottleneck elements (CAN, local switching, junction network, trunk switching) to the same interconnection services provided under National Access. Under the Commission's draft pricing principles, these services should be cost-based.

The Commission considered this approach appropriate because:

- interconnection services are sufficiently similar;
- structure of charges are sufficiently similar with up-front charges and usage charges;
- evidence suggests that the terms and conditions in the Telstra–Optus Agreement are more consistent with the reasonableness criteria that National Access;
- evidence suggests that the Telstra–Optus Agreement includes favourable interconnection charges and conditions from the pre-existing duopoly arrangements (Part 8 of the *Telecommunication Act* 1991); and
- evidence suggests that the National Access tariff includes an amount to recover the costs of Universal Service Obligations (USOs) (service providers using National Access are likely to become carriers on or soon after 1 July 1997 and be required to contribute separately to the USO fund).

The major changes in the determination were to the originating (access) and terminating (egress) services of the National Access tariff.

Capital city

	Pre-existing usage rate (cents per minute)	*Usage rate specified in Commission's determination (cents per minute)*

Access/Egress (8.00am – 10.00pm)	4.24	2.84
Access/Egress (10.00pm – 8.00am)	2.18	1.34

Non-capital city

	Pre-existing usage rate (cents per minute)	*Usage rate specified in Commission's determination (cents per minute)*
Access/Egress (8.00am – 10.00pm)	7.48	5.01
Access/Egress (10.00pm – 8.00am)	4.99	3.07

Non-code access (pre-selection)

Per call non-code access charge (per month) were changed to:

- 3 cents per call attempt for 0 to 850,000 calls per month; and
- 0 cents per call attempt thereafter.

from:

- 3 cents per call attempt for 0 to 850,000 calls per month;
- 2 cents per call attempt for 850,000 to 2,500,000 per month;
- 1 cents per call attempt for 2,500,000 to 5,000,000 per month;
- 0.5 cents per call attempt for 5,000,000 to 8,500,000 per month;
- 0.2 cents per call attempt for 8,500,000 to 25,000,000 per month; and
- 0.1 cents per call attempt thereafter.

PANEL SESSION 1

Invited paper 3

Telecommunications service and access pricing

Philippa Dee
Industry Commission

A key feature of the new telecommunications regime is that industry participants can gain access to certain ‘declared’ services of other participants as a way of providing components of the final package of services they offer their customers.

In this way, the access seekers can compete with the access providers in offering final services to customers, but without having to build all of the facilities themselves. The idea is that this will promote competition in the final service markets, while still allowing for economies of scale and scope that might be lost if the declared facilities were duplicated.

Obviously, a key policy challenge is to get the terms of access right. If the access price is too high, it may deter the socially desirable entry of access seekers, or it may encourage them into socially wasteful duplication. If the access price is too low, it could deter the efficient entry of access providers, or lead to insolvency of the current providers.

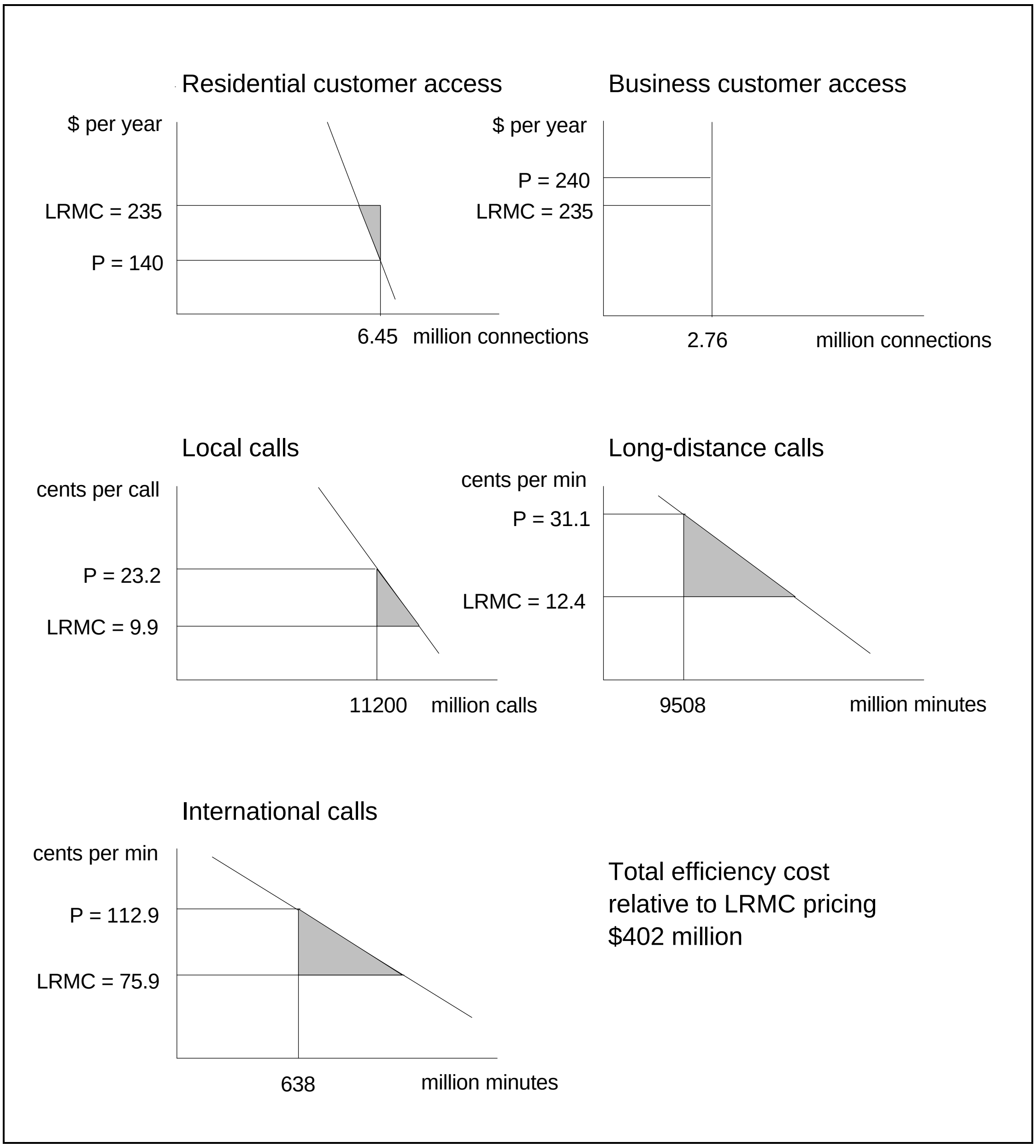
But lest it be thought that the access price is a means of solving all of the problems of the industry, the issue needs to be put in a broader context. In particular, it needs to be set against developments in the pricing of final services. And this in turn raises a second policy issue under the new telecommunications regime — the role of price cap regulation in governing the prices of final services.

Let us consider the situation in final service markets at the moment. We need to consider not just prices, but prices relative to costs. The analysis is drawn from Industry Commission (1997a).

Figure 3.1 shows estimates of Telstra’s long run marginal costs of providing the key basic telecommunications services. These costs include operating costs, depreciation and a return on the capital used to provide the service.

So the estimate of the cost of subscriber access to the network — the resource cost of providing you and I with a copper wire connection from the local exchange to our house, the thing we pay a monthly rental for — covers the operating cost, maintenance and return on the capital used to provide the subscriber access. In technical terms, this part of the network is called the *customer access network*, or CAN. A key feature of these costs is that they do not vary with the traffic through them. They are measured here in dollars per subscriber per year, irrespective of traffic.

Figure 3.1: Pricing of Telstra services 1995–96



The estimate of the costs of local calls covers the operating and capital costs of the dedicated equipment used for the switching and inter-exchange carriage of local calls. In technical terms, this part of the network is called the *local exchange network*, or LEN. The cost of local calls shown in figure 3.1 has been estimated by the average operating and capital cost of the LEN, expressed in cents per call.

Now the CAN and the LEN do not just provide local calls. They are also used to reticulate higher level calls — long distance and international calls. This is a key access issue. Service providers such as AAPT want to offer cheap long distance and international calls, and may be willing to establish their own switching and long distance transmission facilities to do so. But they do not necessarily want to duplicate Telstra’s or Optus’s local switching and transmission equipment — the dreaded black or grey overhead cables. They may prefer to use Telstra’s or Optus’s facilities to complete this part of their higher level calls. I will return to this issue later.

The estimated cost of long distance calls includes the operating and capital costs of the LEN that is used at each end of the long distance call, plus the operating and capital costs of the switching and transmission facilities used to carry long distance calls between local exchange areas, all expressed in cents per minute of long distance call. The cost does not include any CAN costs, because CAN costs are not traffic-sensitive.

The long distance network is used not just for long distance calls. It is also used to reticulate international calls — those that originate or terminate outside of Sydney and Melbourne where Australia’s international gateways are. This raises a second access issue. Up till now, for various reasons, competition for international calls has been concentrated in major metropolitan centres. But as competition spreads to remote regional centres (such as Canberra), new providers may not want to establish their own long-distance switching and transmission capacity to bring outgoing calls to an international gateway. They may prefer to access the facilities of existing carriers instead.

The estimated cost of an outgoing international call includes the operating and capital costs of the domestic and possibly the long distance components required to get the call to the international gateway. It also includes the cost of using the international gateway switch. It includes the transmission cost of taking the call from the gateway to a notional mid-point, half of the way towards the foreign international gateway at the other end. The remarkable thing is that these days, the cost per minute of this international leg is less that a quarter of the total cost so far, and the total cost so far is only 11 cents a minute.

What takes the cost up so dramatically thereafter is that Australian carriers need to make grossly inflated payments to foreign carriers to take the call from the notional mid-point through to termination. We estimate that these costs are 65 cents a minute on average. Industry Commission (1997b) looks at this payment further, and questions whether it is really going to be an impediment to getting cheaper international phone calls in the near future.

Now these cost estimates are nothing more than that — estimates. They have been cobbled together from patchy data in annual reports and AUSTEL publications and guesstimates from industry analysts, because a lot of the data are not publicly available. Even traffic data have not been published recently. Insiders could undoubtedly shoot holes in these estimates. But we think they give a reasonably good indication of orders of magnitude involved.

These service cost estimates do not cover all of Telstra’s costs. They exclude what are known as common costs — an important one is billing costs — that are shared across a number of services. They also exclude corporate overheads. And they exclude a contribution to corporate profits.

So one of the dilemmas in public utility pricing is that if Telstra were to price its final services at long-run marginal cost — normally the preferred benchmark of economists from an efficiency point of view — it would not cover all its costs. It would eventually go out of business.

The policy question is whether there is a way of pricing final services that will also recover common and overhead costs and make a contribution to profit, while doing minimal damage in terms of efficiency. Let us see how Telstra is doing at the moment.

Figure 3.1 also shows Telstra’s current prices for final services, relative to long run marginal costs.

Notice that prices for most services are above marginal cost, particularly for long distance calls. Remember that the price of international calls is also far above the real resource cost of making the calls, but Telstra’s costs have been inflated by the payments it needs to make to foreign carriers.

Notice too that the price of residential subscriber access is below long run marginal cost. This is the so-called CAN deficit that has been talked about in the context of access pricing.

The shaded areas indicate the efficiency losses associated with the current pricing structure. They amount to about $400 million per year.

The question is whether they can be reduced.

Currently, the efficiency loss in the long distance market is relatively high, for example, while that in the subscriber access market is fairly small. The high efficiency losses occur in markets where demand is relatively price responsive. The low efficiency losses occur in markets where demand is not price responsive. The slopes of the curves have been drawn in accordance with available estimates of the relative price sensitivities.

This means that if prices in the high-loss markets could be dropped a bit, and those in the low-loss markets raised a bit, the same total costs could be covered with lower total efficiency loss.

At the extreme, since business subscriber access has been estimated to be completely unresponsive to price, this market could be used to recover all the common and overhead costs, allowing all other services to be priced at long run marginal cost.

Figure 3.2 shows that business subscriber access would need to rise to just under $1300 per connection per year.

The efficiency losses would be reduced to zero. And so would the CAN deficit.

Obviously, a key question is whether business subscriber access would stay completely unresponsive in the face of such a price hike.

Figure 3.3 shows the situation when business subscriber access is capped at a more realistic $350 a year.

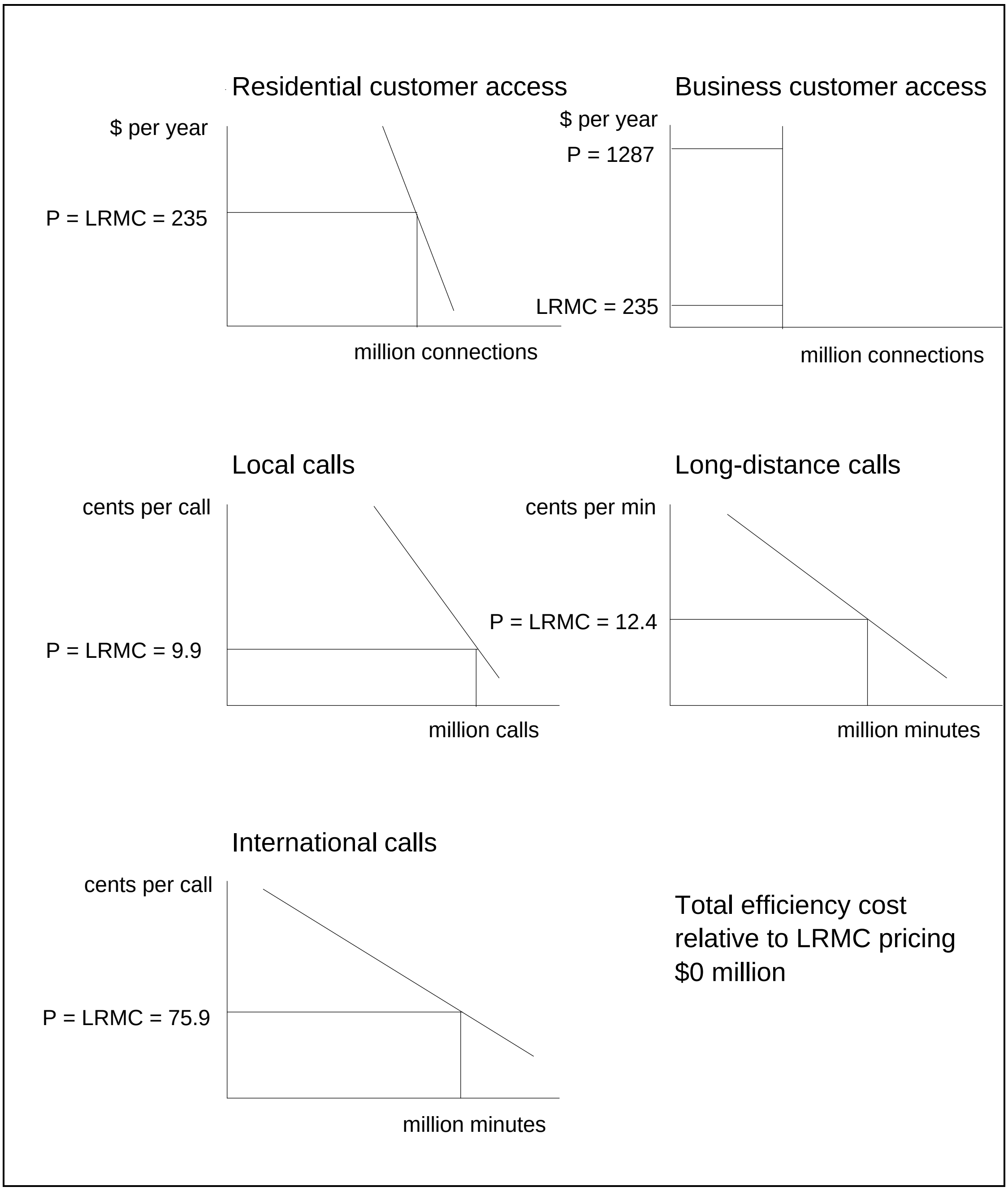
It also recognises two additional constraints that currently apply to Telstra's pricing options. Telstra has been subject to price cap regulation. This is designed to guard against it exploiting its market power to increase profits. The price rebalancing shown so far has kept profits constant, so would not have violated an average price cap. However, Telstra is also subject to price sub-caps that constrain the prices of some individual services. In particular, sub-caps currently prevent increases in residential subscriber charges. They also prevent increases in the price of local calls.

So figure 3.3 shows the best that could be done with business subscriber access at $350, and residential and local call prices where they are currently. Efficiency losses could still be lower than the $400 million currently. But they would still be sizeable, at about $260 million.

They could be reduced even more by relaxing the price sub-cap on residential subscriber access, at least to the point where this was priced to cover long run marginal cost (figure 3.4). The efficiency loss could thereby be reduced to about $100 million — fully $300 million less than is now. All this would require would be a modest increase of about $100 a year in residential and business access charges, allowing reductions in the prices of local and long distance calls.

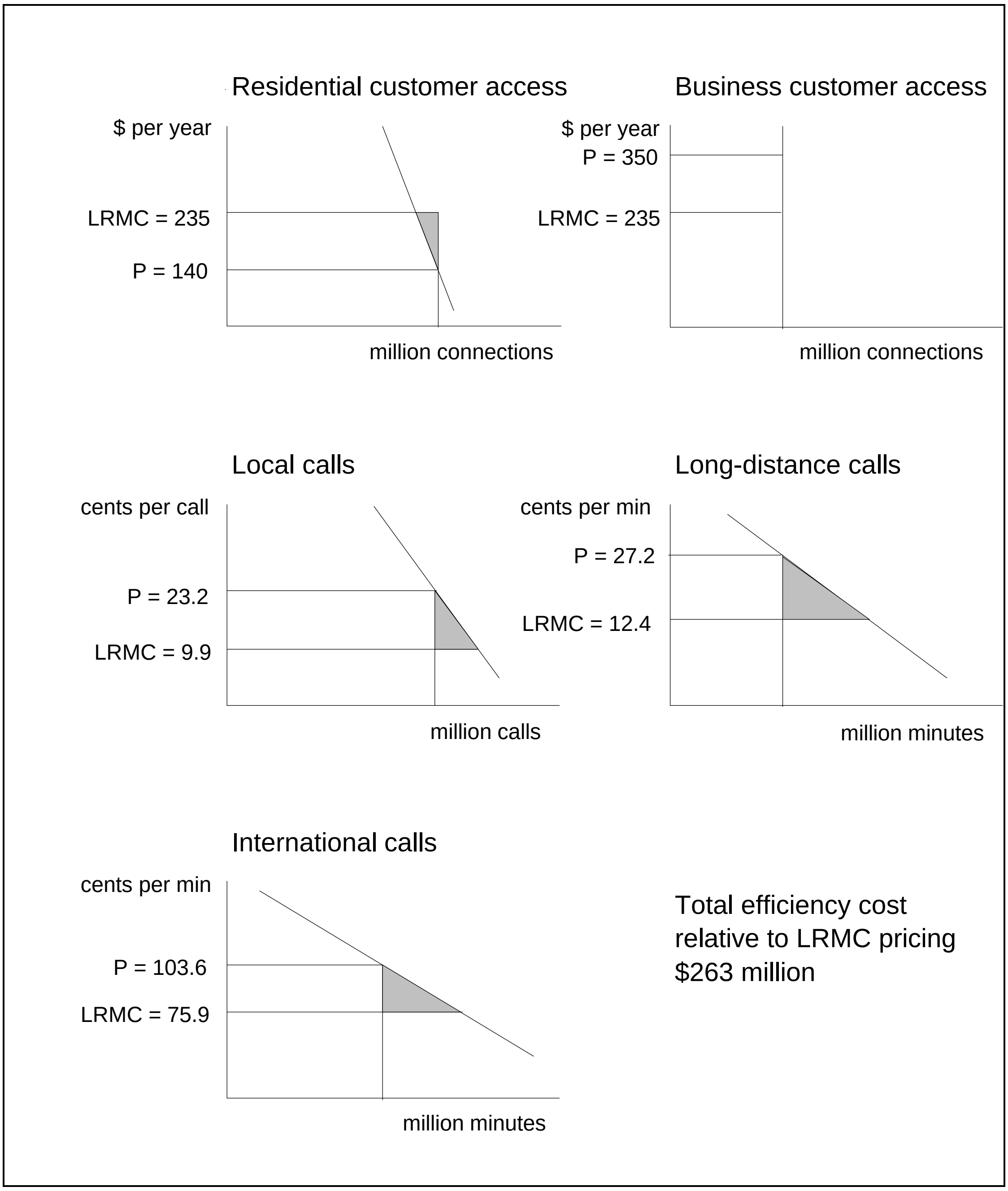
The analysis in Industry Commission (1997a) shows that also relaxing the price sub-cap on local calls could reduce the efficiency losses further, but not by very much at all.

Figure 3.2: Efficient price rebalancing



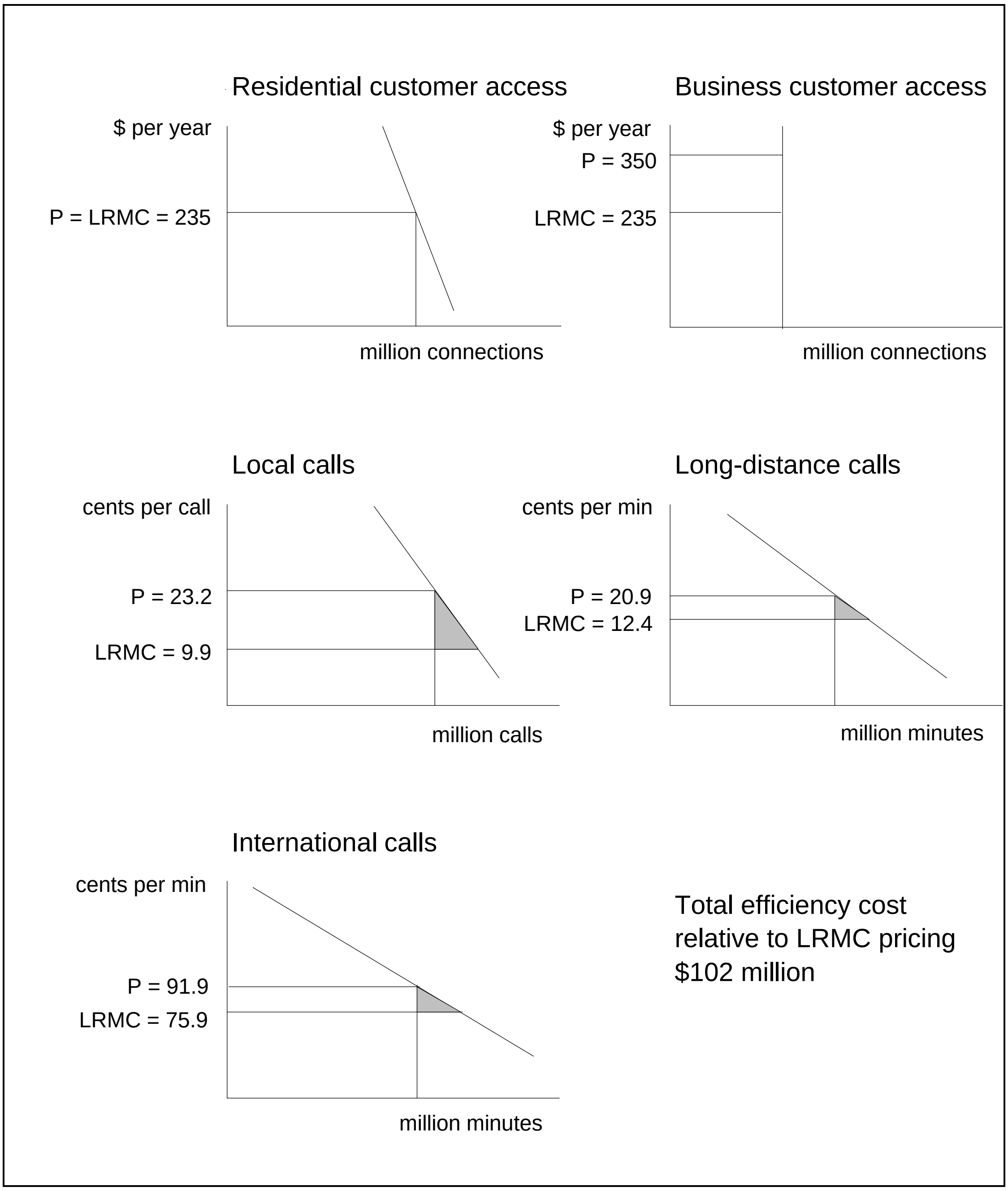
This analysis shows that if the price cap on residential subscriber access were removed, Telstra could adjust its prices to recover its common and overhead costs from final service customers in a relatively efficient fashion. It would not face a CAN deficit. And the cost in terms of efficiency could be considerably lower than currently.

Figure 3.3: Rebalancing within price caps



Thus the price sub-cap on residential access imposes a significant efficiency cost. It prevents Telstra from adopting a more efficient pricing structure, one that would be good for profits, and (according to Baumol, Bailey and Willig 1977) would also be likely to protect it — and us — from inefficient entry.

Figure 3.4: Relaxing the residential sub-cap



The analysis also shows one of the reasons why it would not be a good idea to allow the price of service provider access to the local network to include a contribution to common costs, including CAN costs. This would simply distract attention from more efficient ways of recovering those costs, and cement in place the inefficiencies in final service prices imposed under the current price cap regime.

The second reason is that it is in any event better to recover common and overhead costs from final customers rather than service seekers. Diamond and Mirrlees (1971) long ago pointed out that any pricing or taxing regime that distorted both producer and consumer decisions would be worse than one which raised the same amount of revenue, but distorted consumer decisions only. Thus the production decisions of access seekers are best left undistorted by allowing them access to inputs in the form of the services of existing infrastructure at long run marginal cost. The concept is essentially the same as the total service long run incremental cost (TSLRIC) benchmark the Australian Competition and Consumer Commission (ACCC) has adopted, but in its pure form, without the inclusion of common costs.

Of course, some may argue that the conditions required by the Diamond and Mirrlees result do not hold in telecommunications. In particular, the result requires there to be no excessive or ‘pure’ profits. But if there are pure profits in telecommunications, they would be being reaped in final service markets. In these circumstances, the pricing analysis of Bös (1985) suggests that it is optimal to price up on access if access is a substitute for the service generating the profits, and to price down on access if it is a complement to the service generating the profits. Now the ultimate complementary relationship is one between an intermediate input — the service for which access is sought — and an output — the final services delivered to subscribers. So even here, the analysis suggests that it is appropriate to price down on access.

The ACCC has recently released a determination setting the price of access over a transitional phase to the end of 1997. The price of access to the local network for reticulation of calls in capital cities (through Telstra’s National Access product) has been set at 2.84 cents per minute in peak periods and 1.34 cents per minute in off-peak periods. This is the price of comparable CBD and metropolitan access under the current Telstra–Optus agreement.

The ACCC’s method of arriving at the figures was understandable, given its time constraints and limited access to cost information. The difficulty is that, as far as can be determined, the current Telstra–Optus access price is above long run marginal cost (Industry Commission 1997a, p.115). Thus, ideally, access prices after the transition period should be even lower. The Commission’s analysis suggests an average price of 2.5 cents a minute across both metropolitan and regional areas would be closer to the mark.

The access regime does not guarantee this outcome. If access arrangements can be negotiated between seekers and providers on a mutually satisfactory basis, they need not come to the notice of the ACCC at all. It remains an open question whether this negotiated approach can deliver the sort of access price for telecommunications that has been argued for here — one based on TSLRIC in its purest form.

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PANEL SESSION 1

Comments and discussion

Philip Williams (Melbourne Business School)

Do the ACCC's pricing guidelines rule out the possibility of recovering common costs from multi-pricing regime? You have seen by having the principle of no price discrimination and prices reflecting costs to rule out the option of recovering common costs through some lump sum charge.

Graeme Woodbridge (Australian Competition and Consumer Commission)

I don't think they do. As I said, people can make commercial negotiations any way they like and we, obviously, would consider an undertaking where someone came along and had a multi-part tariff, that is if they want a price, and we would have to assess it against the criteria. So in terms of that there should not be a problem. So I don't see it does. The only implication that it might is that when we arbitrate we have said we are going to use some sort of long running incremental cost approach, total service lowering incremental costs, and it will be a uniform price based on cost. However, that could be used as a base and people could go and negotiate off that if they want and come up with multi-part tariffs.

Philip Williams

Why ever would you agree to pay incremental costs plus a lump sum if you know that the ACCC is not going to ever require you to pay a lump sum?

Graeme Woodbridge

The question is, what is your multi-part tariff? In other words, is it going to be that uniform price or some other price with a high, up-front fee and a lower marginal cost? We would have no control over people going out and probably have no desire to control people going out and striking such an arrangement, if they think, compared to the price that we set.

Jerome Fahrer (Allen Consulting Group)

I would like to ask Graeme what's the ACCC's interpretation of long term interest of the end-users, which is a rather ambiguous term, and in particular does the ACCC have a view on whether this means a consumer surplus criteria or a global surplus criteria, that is which includes the profits of firms in the industry, which might arguably be in the long term interests of consumers and how you see any conflicts between the short term interests of end-users and the long term interests of end-users being resolved?

Graeme Woodbridge

I guess that the way the thing has been approached is we are looking for outcomes rather than we are thinking of what is in the long term interests of end-users. I would think that what is in the utility function, lower prices that are sustainable I would imagine, high quality service and possibly a greater range of products; that is the fundamental thing you would want to assess, and basically short term versus long term. As said in our pricing principles, what we have taken is a long running, incremental cost here, so it gives a return to investment. So it is looking at the long term interests of end-users in that respect.

Peter Forsyth (Monash University)

A question for Henry. When you look at Telecom New Zealand you would think that it would have a lot of market power, particularly since regulation has been withdrawn, price regulation, and you would imagine that it would have quite a lot of scope to increase its prices. Can you give us a bit of perspective on why it seems to be reducing its prices? Is it that competition is strong enough to force it to do so? Is it potential competition or what? One would have thought that if anything it would take advantage of its position and raise prices, yet it seems to be very well behaved so far.

Henry Ergas (Auckland University)

I think there are two fundamental elements there, Peter. The first is that probably initial prices were above profit maximising monopoly levels and I suspect they were so all the more once the price rebalancing had occurred. Essentially, you had extremely distorted prices in New Zealand, much as you now have in Australia, in that rentals were extremely low, particularly in the mid-1980s because they had not risen at all in line with inflation, and virtually all of the costs were being covered out of toll costs, that is out of STD calls.

The prices which you were left in late 1987 made simply no sense at all, and then you had a substantial increase in all rentals and that created the scope to move prices towards more reasonable, economically reasonable levels even for a monopoly. Of course, on top of that, what you were looking at this very substantial reductions in costs which have been achieved at TCNZ. Then TCNZ went from having about, in effect, 23,000 employees in core telephone service to this year having about 6800 employees in the core telephone service, and capital cost also declined very substantially. So you had very substantial reductions in costs and as cost were stripped out even a monopolist would reduce charges and in reasonably price-elastic markets, in particular toll markets, it made good sense to bring prices down.

So there was that element and then the second element was that, yes, you do have quite significant competitive pressure. Again, it is very difficult to measure it, especially when you try to measure potential competition. But even if you just take market share loss to two entrants, Telecom New Zealand has lost more market share to clear in the toll markets than Telstra has lost to Optus. There has been quite a lot of competition in the market. There is a diversity of players and that has also helped to keep Telecom New Zealand more honest than it might otherwise had been.

Having said that, I think it is also fair to note that Telecom New Zealand is fairly profitable. That might be a rather charitable way of putting it. As you would expect, given that they have achieved very significant productivity gains in a sustained way over the course of a decade and you would hope that the way the regulatory regime would work is that it would provide incentives for those productivity gains to be achieved and one of the means by which that has occurred is that Telecom New Zealand has provided shareholders with what are really rather handsome returns.

Martin Algie (Minter Ellison)

It is a question for Henry. It really follows on from the last question focusing on potential competition. You painted a fairly stark distinction between the regulatory structure as its been growing and growing in Australia and a regulatory structure in New Zealand. The 24 pages of legislation, or whatever you said there was, seems to me to neglect one thing and probably a fairly important thing and that is access. Clear communications has had a very difficult time in gaining access. It seems to me that the New Zealand legislature has relied on, I was going to say the good grace of New Zealand Telecom, to either let a potential a entrant in or not, and you can’t refuse if you’re misusing your market power, your position of dominance under Section 36 of the

Commerce Act. But that mechanism does not really appear to have worked. Have you any comment on that?

Michael Cunningham (Queensland Treasury)

Could I perhaps asked a related question and we might get answers to the two questions together? Henry said that the intention of the New Zealand legislation was to constrain Telecom not to shift market share to new engines. The Australian legislation, by contrast, is looking to promote competition of a somewhat different objective. I would just like to hear from Graeme and Henry how they think this difference might work out in terms of getting the gains in Australia which have been realised in New Zealand.

Henry Ergas

The approach, rightly or wrongly taken in New Zealand, has been that of starting from the premise that probably for a very long period of time Telecom New Zealand will be the predominant supplier of most telecommunications services in New Zealand, bearing in mind, of course, that New Zealand is a fairly small country. One implication of that is that you gain - the social welfare gains from productivity improvements at Telecom New Zealand are very large, relative to those which would arise simply from shifting a bit of market share from Telecom New Zealand to Clear or to anyone else. In the sense, if you can bring whole cost structure of Telecom New Zealand down then you get very big gains in terms of the economy and that's really been the primary concern and the primary means or benchmark in terms of which policy has been assessed has been, what has the influence been in terms of getting Telecom New Zealand to be as good as a supplier as it can be.

Obviously not a perfect supplier by any means but to make it as good as it can. There has been much less concern with trying to make life particularly easy for Telecom New Zealand's competitors, and that doesn't mean that Telecom New Zealand can do anything it wants. As you say, there are the protections of the *Commerce Act*, under section 36 of the *Commerce Act* in particular, which prevent Telecom New Zealand from using its market power to all together exclude entry. The result of that has been - Clear has had, I think, a fairly hard time getting access, certainly a harder time than Optus has had in the Australia. Here Optus was handed access on a plate. Whether at the end of the day that has really constrained Clear terribly much is another question.

I don't think it is in terms of access, though not as generous perhaps as they might have been, there has certainly not been such as to blockade or prevent competition from developing in the market. One result of that is that actually Clear has done rather well. I think that one consequence of the New Zealand regime has been to put a great deal of pressure on Clear for Clear to be a well-managed competitor and Clear is a much leaner, meaner firm than, with due respect, I would say Optus is in Australia. Much more focused image in its product range and its marketing efforts and I think been ultimately more successful.

In Australia, in contrast, there's been somewhat of a tendency to confuse the protection of competitors with the protection of competition and what we have had is a regime which has all too often leaned backwards to, almost artificially, create opportunities for the shifting of market share to Telstra's competitors. One important result of that has been that those competitors haven't often needed to compete terribly vigorously to earn reasonable returns to their shareholders. Another result of it has been that those competitors have not had sort of a blow torch applied to them which might have directed them more to consistently take sensible decisions. I think it's really quite striking that despite the fact that inter-connection costs are slightly higher in New Zealand than they are in Australia, you wouldn't find Clear engaging in the kind of whole scale duplication of local loop which Optus chose to engage in.

There's absolutely nothing comparable to this vast investment brace which we have had in HFC in New Zealand. Rather, what is happening is that much more sensibly, there are competitors putting in wireless local loop. The only reason to my mind that we have had this duplication which we observed today in Australia is because of a regime which in seeking to promote competitors provided them both first with the incentives and the means to engage in what was ultimately entirely, socially irrational conduct.

Graeme Woodbridge

I tend to agree with Henry in the sense that it seems the legislation is designed to promote competition where in Australia the early integrated player has control over bottlenecks and also of supplying in those dependent markets or downstream markets. The access regime, or one of the objectives of the access regime, is to allow access to those bottleneck facilities, so you know efficient firms can compete in those markets where their efficiency is based on their quality and their cost production. But is basically open to the number of competitors that will end up being in that market. It is just more of a playing field where people can get access to bottlenecks so they can compete if they re more efficient.

Henry Ergas

You also should note that in the New Zealand case it wasn't Clear that didn't have any trouble negotiating access to the local loop for completion of STD calls, it was really only for the completion of competitive calls undertaken in the same local loop. So it wasn't all abysmal for New Zealand.

Stuart Shephard (Telecom New Zealand)

I think one of the interesting things in the transition from a regulated environment to a competitive one is that the constraints often change from being a price cap to being a commercial consideration and sometimes that mixes up the regulatory process rather badly. One of the examples of that is in your model it seemed to me that you were suggesting that the incumbent would retain all access revenues. However, in practice two things are likely to work against that quite severely. One is the costs of technology are dropping so quickly, it's quite tenable for a new entrant to duplicate access in some but not all areas, particularly CBDs and some suburbia.

Second, it is in the interest of new entrants to gain access because they get customer presence and then can sell other products. So in effect, the revenue that the incumbent would receive from those very inelastic demand schedules that you drew would be constrained by commercial considerations, not the price tag and, therefore, the approach of just raising price caps in some areas to reduce the dead weight loss is unlikely to work in practice. I was wondering if you have considered that and thought about how you could extend your model to take account of that.

Philippa Dee (Industry Commission)

You are right. The model that we have looked at has not treated in a great deal of detail issues to do with what the response of the competitors would be. If you like, we have underlined what we have done as we have implicitly assumed that competitors will actually follow the incumbent when they do all this, which may or may not happen in practice. But to the extent that the lower cost characteristics of potential competitors put commercial constraints on the incumbent, then we would think that that was absolutely precisely what we would want. If, in fact, Telstra can't price up on its crummy old copper wire because somebody else has come in with a wireless local loop then great, that is the way markets work.

Henry Ergas

This is just really a comment on Philippa's charts and builds on the same question. I wonder, Philippa, whether the price elasticity of demand for business lines is actually quite as low you suggest. My main query there is that most business lines are part of multi-line or are held by multi-line businesses and they are used in essentially variable proportions. For example, you can multiplex more or you can use a range of alternatives which allow you to derive much more capacity from single lines. So if you look at the elasticity of demand studies for business lines taking account of multi-line businesses you typically find a relatively high elasticity of demand for the multi-line business.

Philippa Dee

We looked at some of those studies, actually - this is getting a bit technical - studies that we could find suggested a high elasticity over the number of lines given that a decision had already been made to have access of some sort. We weren't sure that that was necessarily relevant to the question of the decision by business to have access at all. But having said that, I take your point and that is why we didn't believe the story about recovering all the overhead costs from business.

Graeme Woodbridge

And I think the efficient process might have relatively, over your kind of sort of quasi-Ramsey process, the lower price for business than for residential consumers.

Chris Pritchard (South Australian Office of Energy Policy)

I would like to ask Graeme Woodbridge a question. There is some emphasis in Australia placed on the ACCC not being terribly interested in arrangements other than undertakings or disputed arrangements or disputed attempts to gain access. Could you just spend a minute or two putting what you said this morning in the context of the broader scope of the *Trade Practices Act* when it might come to looking for being alert to market sharing agreements of the collusive behaviour. How do you put what you said this morning in that broader context?

Graeme Woodbridge

Basically I was trying to draw a distinction between what is under part 11C of the *Trade Practices Act*, which is the set up of the access regime, and that is just a legislative provision. We only have a role in terms of conditions under those two situations, arbitrations and assessing undertakings.

Of course it is quite possible part 11B of the *Trade Practices Act* and other parts of the *Trade Practices Act* may come to play in some sort of anti-competitive behaviour, where in the supply of these declared services or access services generally. So it is not ruling out that type of action. Obviously, the *Trade Practices Act*, they are parts of the *Trade Practices Act* that will apply to those services. It is a question of whether that sort of behaviour goes along with the supplier basis. So that is the context.

Partha Gangopadhyay (University of Western Sydney)

My question is rather clarification. What kind of information structure is there regarding the ...(indistinct)... conditions. Does a new carrier know fully the cost of the incumbent or incumbents?

Henry Ergas

We said many of the entrants, many of the potential entrants, certainly into the Australian market — and if you look at the actual entrants in New Zealand this would be the case — are entities which are involved in telecommunications elsewhere and often as incumbents. For example, in New Zealand we have Bell South which operates a mobile network, Clear which has investment by BT and MCI and so on, and Telstra has a significant presence in New Zealand now. So you would expect that those kind of players would have pretty good information about the cost of providing service and would relatively readily be able to assess what the costs of the incumbent might be.

I think that would also be the case in Australia, certainly given the kind of players which have entered the industry, either in the duopoly years or are doing so now. As far as publicly disclosed information by the incumbent is concerned, not terribly much information is disclosed by incumbents in competitive environments anywhere. I tend to think that that is really quite a good thing in many respects and that it, in particular in cases where might otherwise facilitate coordination between entrants and incumbents, tends to it make somewhat more difficult for that to occur.

But one thing I would say is that, oddly enough, there is more information available in New Zealand than in Australia and one major reason for that is because TCNZ, being publicly listed and having very strong interests in having good quality research being done about it by analysts, actually discloses a very considerable amount of information to analysts. So if you pick up the analysts' reports on TCNZ you get much more information than you could derive by reading the national audits reports on the Telstra accounts.

PANEL SESSION 2

The national electricity market

Donald Anderson
Queensland Electricity Reform Unit

John Salerian
Industry Commission

Joshua Gans
Melbourne Business School

PANEL SESSION 2

Invited paper 4

The Queensland experience in electricity reform*

Donald Anderson
Queensland Electricity Reform Unit

* The following is a summary of Mr Anderson's presentation made at the conference.

The following is a summary of the presentation made by Donald Anderson

The Queensland Electricity Reform Unit (QERU) is currently implementing substantial reform in the Queensland electricity industry. The reform process began at the beginning of July 1996, when the Government commissioned a task-force to prepare a report to advise about the process of reforming the industry. The evidence suggested that the Queensland electricity industry's performance was declining relative to that other states.

The Queensland Transmission Supply Corporation (QTSC) owned Austa, which was the government's electricity generator. Austa controlled 80 per cent of the capacity in Queensland. The QTSC had a number of subsidiary corporations that included the seven distribution boards and the transmission body, Powerlink Queensland. This made QTSC a vertically integrated monopoly.

Under the arrangements of a vertically integrated monopoly, Austa was inefficient, because it was able to pass its costs to the single buyer. Most inefficiencies were in its head office functions. Surplus funds accumulated by Austa were invested in a number of inefficient projects. The high cost of power to consumers had a negative impact on economic activity in the State. Industry assistance to facilitate new projects was widespread in the State, and Community Service Obligation (CSO) payments tended to be discretionary and not well targeted.

The task force's key objective in the state electricity market was to encourage price signals that reflected underlying costs. This was achieved by:

- eliminating or minimising market power;
- establishing new organisations and institutions that acted with commercial objectives;
- having a non-discriminatory access regime into the natural monopoly elements of the industry; and
- eliminating barriers to entry in energy generation and retail supply.

One major reform was that Austa was split into three smaller generators. These generators remained in government-ownership and were corporatised. A fourth corporation, comprising the engineers of Austa, was established. The Government decided that the seven distribution boards retained because of regional policy objectives.

Other major reforms include establishing three trading enterprises and seven distribution boards. The Government decided that there should be links between the distributors and the retailers. The three northern distributors are now in an incorporated joint venture which owns a single retailer, the three central distributors are in an incorporated joint venture which owns the central retailer, and the southern distributor owns the southern retailer.

When the task-force was deciding the break-up of Austa, the issue arose of how many Austa-ettes would be an efficient number. Splitting Austa into three smaller companies would result in economies of scale losses of approximately 5 per cent. The gains from splitting Austa would need to be greater than 5 per cent to compensate for the split. The loss of scale economies for coal contracts were minimal since coal contracts were negotiated at the plant level.

There are some other areas of reform. Powerlink Queensland, which was previously a subsidiary of QTSC, the transmission company, was separated out as a single entity. It is going to depend on the regulator for its returns. There is a new corporation responsible for system control and market operation. It will operate as either a separate corporation or a ring-fenced operation within Powerlink. The first tranche of contestable customers will hit the market on January 1 next year, three months after the start of the market. By the year 2000 all customers in Queensland will be contestable. And, it is hopeful that the regulatory functions of QERU will eventually be passed onto the Queensland Competition Authority.

The task force is also involved in a number of other issues. Queensland's geographic distances necessitate the development multiple pool zones. These are currently being developed. Given that there is Government undertaking for uniform pricing, remote zones are likely to attract CSO funding.

As of July 1 the new retail corporations will be launched. QERU has been working on defining the rules and regulations for the establishment of the new market and licensing arrangements and code issues. QERU is also working on establishing the retail price paths, and the establishment of an environmental code of conduct.

These reforms have facilitated economic development in Queensland. There is a substantial reduction in the uncertainty about the delivery of natural gas from Papua New Guinea, which will be used to fuel power stations down the cost of Queensland. There is also substantial interest from independent power producers to build coal-fired power stations in the Serap basin, and to build small gas units throughout Queensland.

PANEL SESSION 2

Invited paper 5

Evaluation, market power and transition pricing in the Australian electricity market

John Salerian
Industry Commission

5.1 Introduction

Australia is in the process of establishing a national electricity market. The objective is to develop a market that operates as close as possible to the concept of economic efficiency by creating competition in those components that are contestable. However, the technical nature of electricity production and transmission still requires a significant amount of regulation to create and run an electricity market that produces market outcomes consistent with economic efficiency.

The way in which the market is regulated can affect the degree to which the operation of the market is economically efficient. In addition to short term efficiency considerations, the operation of the market has important consequences for the way in which augmentation of both transmission and generation will take place. One important issue is whether the design of the electricity market will lead to an efficient system of transmission and generation in the long run.

Recently, there has been an increase in research relating to regulation of the industry and pricing issues, particularly on the pricing of electricity transmission in networks. For example, in 1996 there were several theoretical articles published in the Journal of Regulatory Economics (see Wu et al. 1996; Chao and Peck 1996; and Bushnell and Peck 1996).

A theme emerging from these articles is that some of the principles underlying proposals on the regulation of electricity markets are so-called ‘folk theorems’ — that is, they are commonly accepted assertions about the economic principles that in fact do not apply to the electricity market. For a discussion of these, see Wu et al. (1996).

Wu et al. (1996) claim that these assertions arise because the economic principles being applied are borrowed from other applications of economics, such as transport economics. However, the technology of electricity production and transmission is such that principles from other applications are inappropriate for the electricity market.

This paper, in part, aims to illustrate the economic principles embodied in an economically efficient electricity market through the use of a mathematical programming model of a hypothetical market. This model is an extension of a model previously developed as part of the Industry Commission’s study of the South Australian electricity industry. For that study, the Commission developed a mathematical programming model of the electricity industry in South Australia to evaluate market power issues (IC 1996a). Although the model included dynamic transmission losses, it did not include the externality associated with electricity flows in a network that arise because of Kirchoff's laws (see Chao and Peck 1996 for a discussion). It is this part of the electricity technology that distinguishes the economic principles required for electricity markets from those applicable in other markets.

The aim of this paper is to present an economic model of an electricity market that includes the unique characteristics that arise because of the nature of the technology used in electricity markets. This is achieved by revising the methodology used to represent the transmission. In the model presented here, the power flow equations and variables for a network are included, based on the methodology outlined in Chao and Peck (1996).

The model is then solved for a hypothetical electricity market involving 12 generators distributed around a network consisting of four nodes. Demand for electricity takes place at two of the nodes. The model represents an annual market consisting of 34 time periods, that is, the 8760 hours in the year have been allocated to 34 time periods (load blocks).

The results are then used to illustrate some of the economic issues that arise in electricity markets. The model is also used to illustrate how the addition of a transmission link can affect all transmission links, nodal prices and merit order dispatch of power stations.

The structure of the paper is as follows. The mathematical programming methodology is outlined in section 5.2. To set the scene, section 5.3 presents the structure of the hypothetical electrical market used in the model. Section 5.4 describes the formal model used here. Section 5.5 outlines the methodology relating to the demand for electricity. Section 5.6 outlines the methodology for the transmission of electricity and section 5.7 describes the methodology used for the production of electricity. In section 5.8 the two scenarios to be simulated are described. The results for the simulations are described in section 5.9. Section 5.10 is the conclusion and suggestions for further research.

5.2 Mathematical programming methodology

Samuelson (1952) showed that it was possible to construct a maximisation problem that guarantees fulfilment of the conditions of perfectly competitive equilibria among spatially separated markets. This provided the opportunity to use mathematical programming to simulate market behaviour. Later, Takayama and Judge (1971) significantly extended the applicability of the technique by showing that the competitive and monopoly models could be formulated as quadratic programming models.

Takayama and Judge (1971) also showed that two alternative formulations, the quantity formulation (primal) and the price formulation (the purified dual of the primal) could be used. Takayama and Woodland (1970) proved the equivalence between these two formulations. Takayama and Judge (1971) also showed that the quantity and price formulations could be combined to form another maximisation problem where both quantity and price are explicit variables in the model — this is the 'general' formulation referred to by MacAulay (1992) and is sometimes referred to as the 'self-dual' and 'primal-dual' formulations. Takayama and Judge (1971) also refer to it as the net social revenue formulation.

The general formulation has wider applicability. For example, it applies where interdependent demand functions do not satisfy the integrability condition (that is there is no unique solution to their integration) or where policy requires constraints on both prices and quantities.

In this particular study the quantity formulation has advantages over the general formulation. First, it reduces the number of variables and equations, which is important when dealing with large scale models. Second, it is easier to explain the technique and develop and implement the model using the model generating software, GAMS.[1] This is important when the time to complete the study is short. For similar reasons, the mathematical programming used here has advantages over other related techniques used to compute economic equilibria, such as non-linear complimentary programming and computable general equilibrium models.

In electricity markets, costs and demand conditions vary by time and from place to place. For example, electricity demand can be met by generation from a range of technologies (gas and coal), a range of plant sizes or imported via transmission lines from interstate. Therefore, spatial–temporal models, which include elements of networks, are particularly useful to capture this complexity.

Theoretical developments and application of this methodology to study pricing and deregulation in spatial energy markets increased during the 1980s. Some examples include Salerian (1992), Kolstad (1989), Provenzano (1989), Uri (1989), Hobbs and Schuler (1985), Sohl (1985) and Uri (1983).

In the mathematical programming model developed here, the supply of electricity is represented by mathematical programming models of power stations and transmission, rather than as supply functions. Mathematical programming has been widely applied to electricity supply, primarily to

1 For more information on the GAMS computer software package see: Brooke, Kendrick and Meeraus (1992); Meeraus (1983); and Bisschop and Meeraus (1982).

evaluate the least cost options to meet pre-determined demand. That is, demand is exogenously specified. Examples include Scherer (1977) and Turvey and Anderson (1977). Two Australian applications of note are the Australian Bureau of Agriculture and Resource Economic's (ABARE) version of the MENSA model (Dalziell, Noble and Ofei-Mensah 1993) and the Commonwealth Scientific and Industrial Research Organisation's earlier version of the MENSA model (Stocks and Musgrove 1984).

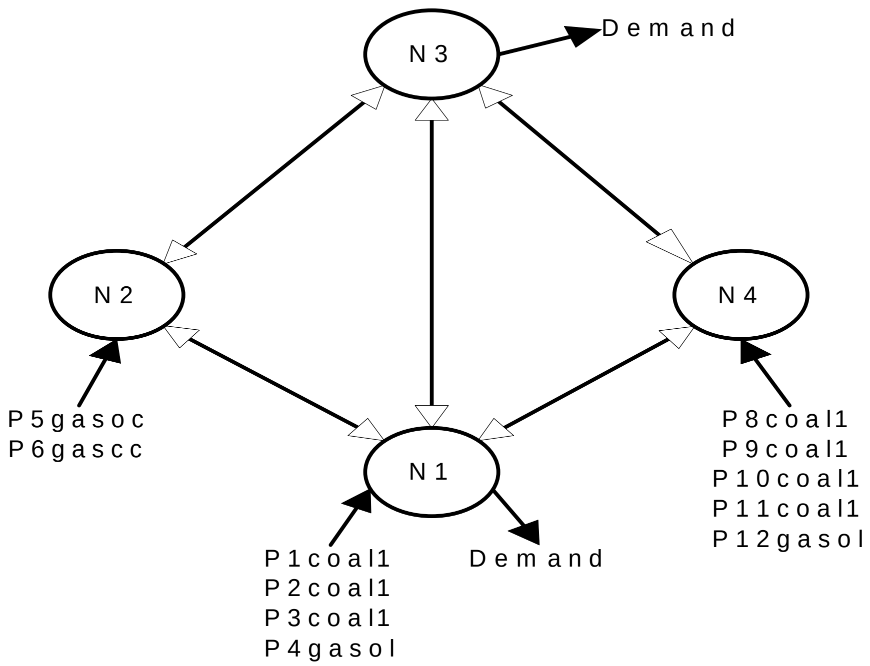
An advantage of the model presented here is that the quantity demanded (and price) is endogenous to the model.

5.3 Structure of an electricity market

A hypothetical network is used in this study. It is made up of four interconnected nodes — N1, N2, N3 and N4 (see figure 5.1).

Demand for electricity takes place at nodes N1 and N3. Generation can take place at nodes N1, N2 and N4.

Figure 5.1: Structure of the hypothetical electricity market



There are two nodes that only generate electricity — N2 and N4 — that is, they have only have generators that supply electricity to the network. Whether or not the node supplies electricity to the network depends on the types of generators that are situated at the node, the demand period and other constraints on the network. For example, there are five generators at node N4 — four coal, one gas — that represent ‘base load plants’ and ‘intermediate load plants’. This suggests that this node will supply electricity in the base period, and consequently in all periods. There are two generators at node N2 — representing gas open-cycle and gas-combined cycle generation — that are ‘peaking and intermediate plants’. This suggests that N2 will supply electricity in peak periods if there are no constraints on the network, but may supply off-peak if other constraints on the network exist. The latter case is examined in more detail in section 5.9.

There is one node that both generates and demands electricity — N1. This node can be thought of as a city load centre with some generation ‘close’ to it. Like node N4, node N1 has a combination of base load and intermediate load plants — three are coal fired and one is gas fired. Since N4 also has demand at the node, whether or not it supplies electricity to the network again depends on the types of power stations at the node, the demand period and other constraints on the network and also the amount of demand at the node.

There is one node that only demands electricity — N3. This node can be thought of as regional load centre with no generation nearby and is always an importer of electricity.

5.4 Mathematical model

This section formally describes the model used in this study. As mentioned in the previous section, the model presented here simulates the economically efficient market equilibrium. Wu et al. (1996) refer to this as economic dispatch.

The model used here has some non linear variables in both the objective function and constraints. It also has some variables that can have negative values.

Notation

For convenience, the notation used here to present the model is based on the GAMS computer modelling language. The notation used to present the model is divided into sets and subsets, parameters and variables.

Sets and subsets

b = set of time periods (load blocks)

n	=	set of nodes in the network
p	=	set of generating plants
d(n)	=	set of nodes where there is demand for electricity
gr(n)	=	set of nodes where generators are located
ng(n,p)	=	set of generators at each node
lk(n,np)	=	set of nodes that are directly linked in the network (node links)
nt(n)	=	set of nodes for which voltage phase angle variables exist

Parameters

Demand		
a(n,b)	=	intercept of the inverse linear demand function for each node in each time period
w(n,b)	=	slope of the inverse linear demand function for each node in each time period
Generation		
plantcost(p)	=	annualised fixed costs ($ million/GW) of each generator
opcost(p,b)	=	operating (fuel) costs ($ million/GW) — adjusted for the duration of each load block
genmax(p)	=	maximum allowable capacity of plants (MW)
pdata(p,'avail')	=	proportion of installed capacity available for use
Transmission		
number(n,np)	=	number of transmission lines between nodes
v(n,np)	=	transmission line voltage (kV)
r(n,np)	=	transmission line resistance (ohms)
x(n,np)	=	transmission line inductance (ohms)
gridcap(n,np)	=	transmission capacity (MW)

Variables

QS(n,b)	=	amount of electricity supplied by each node in each time period (GW)
QD(n,b)	=	amount of electricity demanded by each node in each time period (PWh)
THETA(n,b)	=	voltage phase angle at each node in each time period (radians) — these are free variables that can have negative values
QGO(n,b)	=	output of each plant in each time period (GW)
QGC(p)	=	installed capacity of each plant (GW)
QP(n,np,b)	=	quantity of power flow between each node in each time period (GW) — these are free variables that can have negative values
NSW	=	net social welfare ($ million)

Equations

Objective function ($million)

```
NSW = sum((n,b)$d(n),(alpha(n,b)*QD(n,b)+0.5*ibeta(n,b)*(QD(n,b)**2)))
  - sum((p,b),opcost(p,b)*QGO(p,b))
  - sum((p),plantcost(p)*QGC(p))
```

The objective function maximises net social welfare (measured as consumer plus producer surplus — the area under the demand curve minus the sum of the variable costs). The first right hand side term in the equation is the area under the demand curve (integral of the demand curve). The second and third terms are the variable operating costs of the power stations and the annualised fixed costs of each GW of generating capacity for power stations.

Installed capacity balance (GW)

```
QGO(p,b) =l= QGC(P)*pdata(p,'avail')
```

This equation ensures that the output of each power station in any time period is less than its available installed capacity.

Maximum generation capacity constraint (GW)

```
QGC(p) =l= pdata(p,'units')*pdata(p,'genmax')/1000
```

The maximum generation capacity constraint ensures that the amount of capacity installed is no greater than the maximum allowed capacity specified for each plant.

Node supply (GW)

```
QS(n,b) =l= sum(p$(ng(n,p)),QGO(p,b))
```

The supply (injection) of electricity at a node at a point in time must be less than equal to the output of generators operating at the node at that time.

Real power flow equation (MW)

```
QP(n,np,b)*1000 =e=  g(n,np)*(v(n,np)**2-v(n,np)*v(np,n))
  + y(n,np)*v(n,np)*v(np,n)*THETA(n,b)$nsa(n)
  - y(n,np)*v(n,np)*v(np,n)*THETA(np,b)$nsa(np)
  + 0.5*g(n,np)*v(n,np)*v(np,n)*(THETA(n,b)$nsa(n))**2
  - 0.5*g(n,np)*v(n,np)*v(np,n)*2*THETA(n,b)$nsa(n)
    *THETA(np,b)$nsa(np)
  + 0.5*G(n,np)*v(n,np)*v(np,n)*(THETA(np,b)$nsa(np))**2
```

The amount of real power flow is related to the physical characteristics of the transmission line between the two nodes — its voltage, impedance and resistance — and the difference between the voltage phase angle at the node at each end (see Chao and Peck 1996 for a description). The real power flow equation uses an approximation of Kirchoff's laws to determine the amount of real power that flows between two nodes, including transmission losses. The approximation is valid for small differences in voltage phase angles, which is the case under normal operating conditions. The approximation formula also ensures that the loss equation is convex.

The power flow variable is a free variable and there is one variable at each end of the link between two nodes. By convention, a negative value means power is being delivered to the node via the link. A positive value means that power is being exported from the node via the link. The sum of the two power flow variables on each link is the total transmission loss over the link.

The variable, theta, is the voltage phase angle and is a free variable. The number of voltage phase angle variables is equal the number of nodes less one.

Supply and demand balance (GW)

```
QD(n,b)$d(n)*(1000/hours(b)) =e= QS(n,b)$gr(n)
  - sum(np$lk(n,np),number(n,np)*QP(n,np,b))
```

The supply and demand balance states that the quantity of electricity demanded at the node in any time period must be equal to the sum of the quantity of electricity supplied at the node and the net power flow imported or exported at the node.

Transmission capacity constraint (GW)

```
number(n,np)*QP(n,np,b) =l= gridcap(n,np)/1000
```

The transmission capacity constraint ensures that the total amount of power transmitted between the nodes in any time period is no greater than the maximum (thermal) capacity along that link.

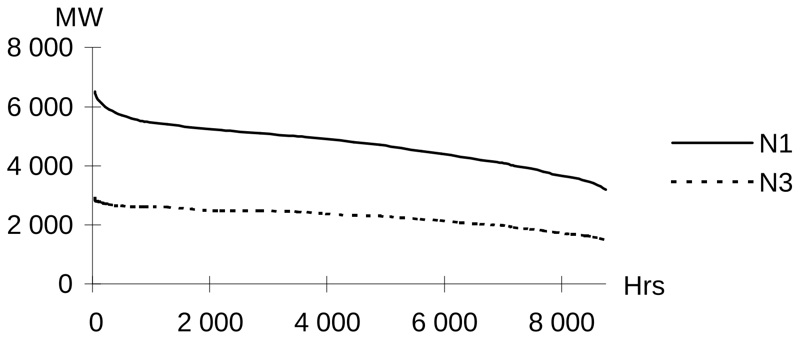
The full model description in the GAMS programming software is in Appendix A.

5.5 Demand

For each node, the load duration curve provides a useful description of demand across the year (see figure 5.2).

With a single node, the load duration curve is obtained by arranging the hourly loads at that node during the year into descending order (Turvey and Anderson 1977; Scherer 1977). However, in a network with more than one demand node, there is an additional complexity introduced because the demands at each node must be for the same points in time.

Figure 5.2: Load duration curve for nodes N1 and N3



To ensure that demand at each node are coincident in time, the following procedure is used. First, the load duration curve for one node (N1) was derived in the manner described above. Second, the load duration curve for the second demand node was determined using the chronological order of loads from the load duration curve in N1. This method was chosen because of its practical convenience. However, the method introduces some averaging issues into load duration curves of nodes other than the base node, N1. This means that the share of the implied load duration curve for N3 may differ from that of its actual load duration curve. It would be useful to further investigate the effects of any bias and consider alternative methods for determining load blocks.

Thirty four demand periods are defined by dividing the load duration curve for the first node into 100 MW blocks. This creates load blocks of unequal duration, measured in hours. Each of the 34 load blocks is assumed to have an independent linear demand function that relates the amount of electricity demanded to its price.

In this study, the demand function is:

$$\text{Price} = a + w * \text{Quantity}$$

This means that the quantity (and price) of electricity is endogenous. Any other effects on demand are assumed exogenous and are implicit in the constant term of the demand function.

The parameters of each demand function, a and w, are calibrated using given prices and quantities and an assumed own-price elasticity of demand, E, by:

$$a = \text{PRICE}\ (1 - 1/E);\ \text{and}$$

$$w = 1/E * P/Q$$

Here the price-elasticity of demand is assumed to be -0.3.

5.6 Transmission

The presentation here is based on that of Chao and Peck (1996). The real power flow in a network, based on Kirchoff's laws, is given by:

$$Q_{ij} = G_{ij}V_{ij}^2 - G_{ij}V_iV_j\cos(A_i\text{-}A_j)+Y_{ij}V_iV_j\sin(A_i\text{-}A_j)$$

where Q is the power flow from node i to node j and G, V and Y are parameters relating to resistance, voltage and admittance. A is the voltage phase angle at each node. The voltage phase angle and the power flow can be negatively valued. When the power flow for Q_{ij} is negative, the power flow is from node j to node i. The transmission loss along the line is given by $Q_{ij}+Q_{ji}$.

Under normal operating conditions, the real power flow equations can be approximated by the following convex function:

$$Q_{ij} = G_{ij}(V_{ij}^2 - V_iV_j) + Y_{ij}V_iV_j(A_i\text{-}A_j) + G_{ij}V_iV_j(A_i\text{-}A_j)^2$$

In this power flow equation, the marginal transmission losses are higher than the average transmission losses and the losses increase with power flow. This creates a rent on the transmission of electricity, so that the value of electricity exported (sold) out of the network exceeds the value of electricity imported (purchased) into the network. This rent represents the income earned by the whole of the transmission network.

There will be an additional rent earned by the network if one or more of the transmission links is constraining, that is at it maximum transmission capacity. The marginal value or unit price of any transmission constraint is given by the shadow price or value of the Lagrangian value associated with the constraint on the transmission capacity. These rents have been termed the 'merchandising surplus' by Wu et al. (1996).

Each of the nodes are connected by links made up of a number of transmission lines. The assumed technical properties of the transmission lines and the assumed maximum transmission capacities along the link are described in table 5.1.

Table 5.1: Characteristics of the network

			Transmission lines			
Link	*Link capacity (MW)*	*Distance (km)*	*No.*	*Voltage (kV)*	*Resistance (/km)*	*Impedance (/km)*
N1⇔N2	3 000	150	6	330	0.03	0.3
N1⇔N3	1 500	375	4	500	0.025	0.25
N1⇔N4	1 500	150	2	330	0.03	0.3
N2⇔N3	3 000	450	5	330	0.03	0.3
N3⇔N4	2 000	400	2	330	0.03	0.3

The distance between nodes plays an important role in determining the overall characteristics of the line. For example although the same type of line links nodes N2 and N3 and nodes N2 and N1, the overall characteristics of the line vary significantly. In particular, the total resistance along a line between N2 and N3 is three times as great as the total resistance between N2 and N1 because the distance between N1 and N3 is three times as great as the distance between N2 and N1.

5.7 Production model

The amount of electricity supplied in each period by a node with generators is the sum of the amount of electricity generated by all plants at that node in that period.

The amount generated at the node is limited by the technical capabilities, operating capacities and costs of the plants at the node (see table 5.2). A plant's output in any period can be no greater than its installed capacity, which in turn can be no greater than the maximum available capacity of the plant.[2] For example, although the maximum capacity that exists at node N1 in any period is 4021 MW (reflecting the maximum capacities of the plants at the node) the maximum supply from the node may in fact be limited to be a smaller amount if the installed capacities at any plant are less than the maximum (reflecting the cost of installed capacity). The different cost structures of plants also place constraints on the order and time that plants are loaded. This 'merit order' means that base plants supply electricity in off-peak periods, while base and intermediate plants supply electricity in intermediate periods, and base,

[2] With maintenance and other outages, the output is usually less than the available capacity. However, in this case availability is assumed to be 100 per cent.

intermediate and peak load plants all operate to supply electricity in peak periods.

These principles are readily applied in mathematical programming models (see Munasinghe 1990). The model used in this study is based on that of Turvey and Anderson (1977) and is similar to others, such as ABARE's MENSA model (Dalziell, Noble and Ofei-Mensah 1993) and the Industry Commission's model assessing the potential for market power in electricity supply in South Australia (IC 1996b).

Table 5.2: Plant data

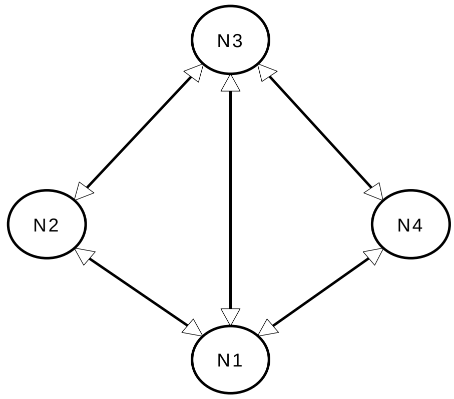
Node	*Power station*	*Availability*	*Maximum allowable capacity (MW)*	*Fuel cost ($ per MWH)*	*Capacity ($m per MW)*	*Life (years)*
Node 1	P1coal1	1	1 270	14.8	1.2	30
	P2coal1	1	861	14.3	1.4	30
	P3coal1	1	2 540	14.3	1.3	30
	P4gasol	1	500	18.5	1.2	30
Node 2	P5gasoc	1	unlimited	32	0.5	30
	P6gascc	1	unlimited	23.5	0.85	25
Node 3	P7dist	1	unlimited	150	0.3	30
Node 4	P8coal1	1	1 268	12.1	1.45	30
	P9coal1	1	960	13.0	1.3	30
	P10coal1	1	1 268	12.2	1.4	30
	P11coal1	1	890	14.8	1.25	30
	P12gasol	1	400	18.5	0.8	30

5.8 Scenarios modelled

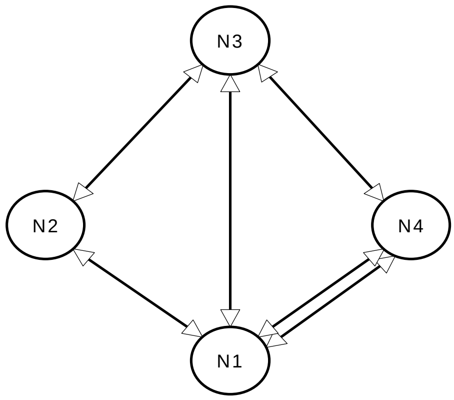
As the market develops through time extra generation capacity could be installed or existing capacity removed and new demand centres could develop or existing ones could contract. While these changes in themselves affect market outcomes, they are not modelled in this study. Rather, the study concentrates on how changes to the network itself - through the augmentation or creation of additional links between nodes - affects the real power flow between nodes and the market outcomes. In order to do this, two scenarios are considered (see figure 5.2) and their outcomes compared.

Figure 5.2: Time scenarios

Scenario 1



Scenario 2



An additional line is added between nodes N1 and N4, increasing its transmission capacity.

5.9 Results and policy discussion

Once the physical properties of electricity flow are considered, changes in one area of the network will affect all lines and nodes. For example when transmission along one link in the network is constrained, it not only affects the power supply to the nodes that it joins but may also affect every other link in the network, every other node and consequently all generators and demand throughout the network. Similarly, augmenting a link between two nodes or creating a new link between nodes that are not currently connected may have far reaching, and perhaps unexpected consequences elsewhere in the network. It may be the case that augmenting an existing link (or building a new one) may be beneficial to the nodes that either link connects and profitable for the owner of the link, but will decrease the overall welfare in the entire network if there are large adverse effects in other parts of the network which offset the benefits at the link. Or it could be that potential links that increase the overall welfare of all participants in the network are not built because of the adverse effects on certain existing participants.

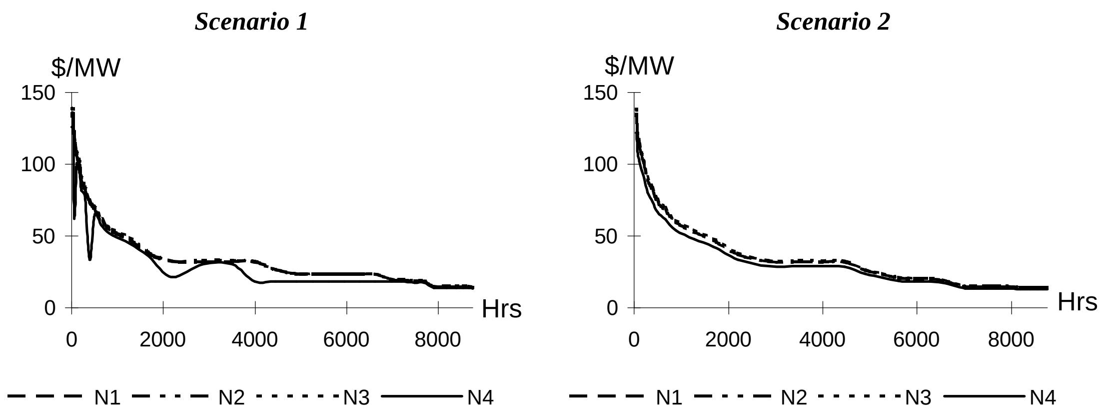
Scenario comparisons

Some of the effects proposed above can be illustrated by comparing the market outcomes between Scenario 1 and Scenario 2 over all periods (see figure 5.3). These effects are examined in more detail through a comparison of the power flows, node prices and merchandising surplus at three distinct time periods - a base load period, an intermediate load period and peak load period (see figures 5.4 and 5.5). It is also interesting to compare the merit order of plant dispatch at various nodes under the different scenario to see the effect of the linkage on individual plants at nodes (see figure 5.6).

Nodal prices

The model is 'price endogenous' meaning that prices are chosen as part of the solution. As expected the prices are higher in peak load periods and lower in base load period (see figure 5.3).

Figure 5.3: Nodal prices — all nodes, various scenarios



An interesting feature occurs at the very peak demand periods. Here the competitive market solution involves rationing supply so that demand is not satisfied rather than dispatching further high cost plants to satisfy very high demands. Consequently at the very peak demands prices increase even further.

Without transmission constraints (Scenario 2), prices are approximately the same in all periods. In contrast, when there are transmission constraints that limit the supply of electricity from node N4 (Scenario 1), the nodal price at the node varies significantly from those seen at other nodes.

Power flows and nodal prices

The power flows and nodal prices for peak load, intermediate load and base load periods are illustrated in figures 5.4 and 5.5.

In Scenario 1, the market outcomes at peak load and base load are as expected — power flows from nodes with low nodal prices to nodes with high nodal prices. At peak load, all plants are operating and node N2 (with the peak load plants) is supplying electricity into the network. Although power flows through the link N1⇔N2⇔N3 in the base load period, node N2 does not supply any electricity to the network. Rather the flows reflect the link's use as an alternative route for electricity supply, reflecting the operation of Kirchoff's laws.

An interesting outcome occurs at the intermediate load. Here transmission between nodes N1 and N4 is constrained by the maximum grid capacity along the link. The amount of electricity that node N4 supplies directly to node N1 and indirectly to the system through node N1 is limited. Equally importantly, the constraint between nodes N1 and N4 also constrains the amount of electricity that node N4 supplies directly to node N3 because of the effects of Kirchoff's law. As a result of the combination of these factors, node N2 now supplies electricity to nodes N1 and N3 — and does so even though N3's nodal price is less than N2's costs. Similarly node N1 sells to node N3 for a demand price less than its costs. In this case nodes N1 and N2 supply electricity below costs in order to alleviate bottlenecks elsewhere and are compensated for doing so by other nodes in the network.

As expected, in Scenario 2 the direct effect of augmenting the link between nodes N1 and N4 allows more power to flow along that link in all periods — which also removes the constraint on transmission experienced in the intermediate period in Scenario 1. Now power always flows from nodes with low nodal prices to nodes with high nodal prices.

Figure 5.4: Power flows under different scenarios — peak, intermediate and base load

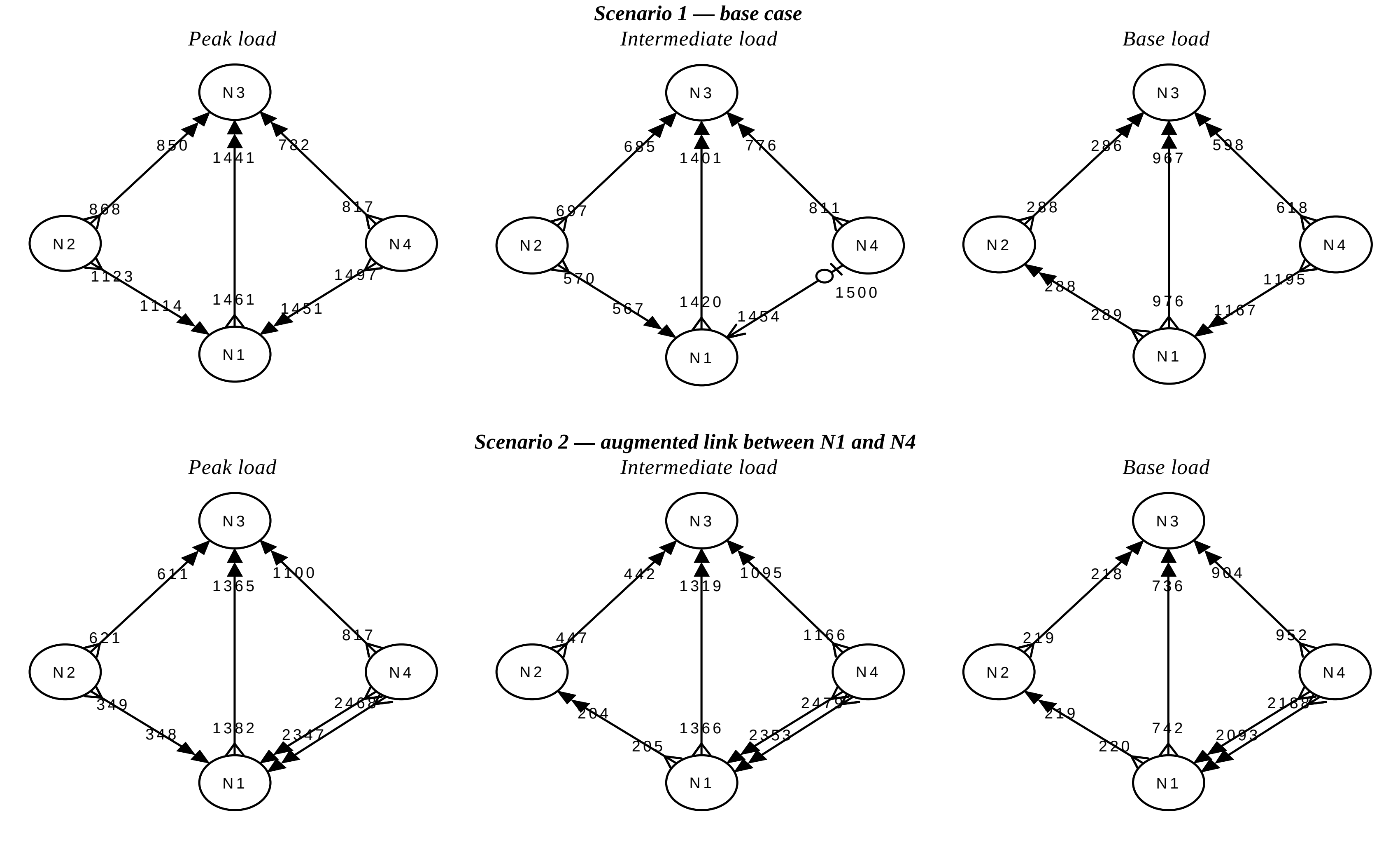
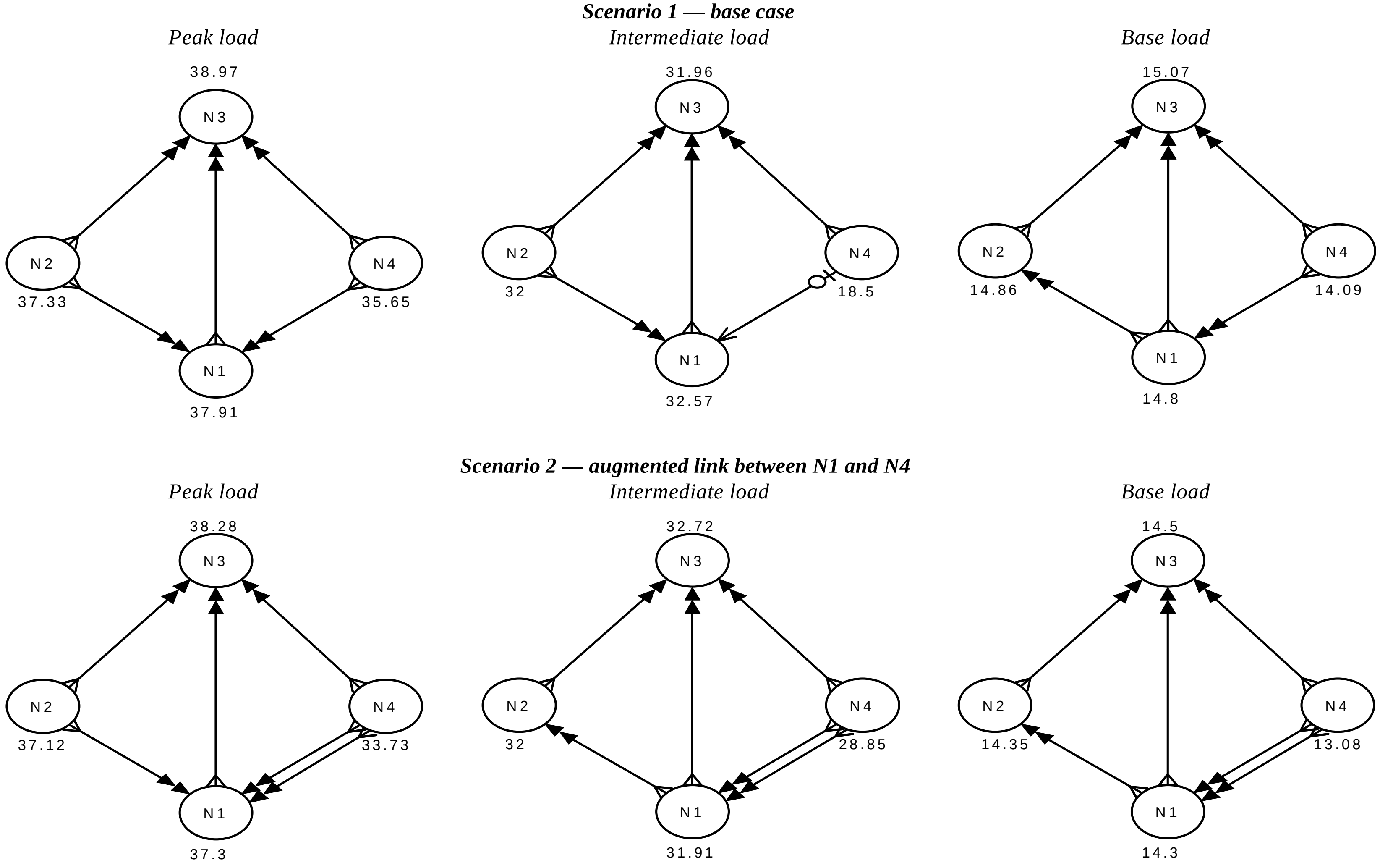


Figure 5.5: Nodal prices flows under different scenarios — Peak, intermediate and base load



The augmented link also affects other links in the network and the activities of generators at other nodes in the network. For example, as in Scenario 1, at peak load all plants operate and node N2 supplies electricity into the network. However, the amount that node N2 supplies at peak load is less than the amount it supplies in Scenario 1, since more can be supplied by the lower cost plants at nodes N1 and N4. Similarly, the amount that node N2 supplies at intermediate load is smaller than the amount it supplies in the base case. Although node N2 still supplies electricity to node N3, this electricity is not all produced at N2. Rather, node N2 produces some electricity but also receives electricity from node N1 to be supplied indirectly to node N3. Finally, at base load, node N4 can now supply more electricity directly to node N3 than it could in the base case, which lessens the amount that is supplied to node N3 from node N1.

Merit order for plant dispatch

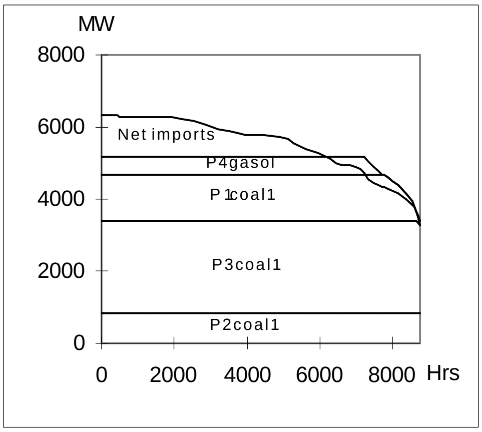
The modelling also provides the merit order for dispatch of generators at the generating nodes under the different scenarios (see figure 5.6).

In both scenarios, power stations are dispatched in order of marginal cost at the node — that is from least cost to high cost. For example, at node N1, the base/intermediate plant node, supplies electricity over all loads. Here the low cost power stations, P2coal1 and P3coal1, are dispatched first then P1coal1 is dispatched and finally the higher cost power station, P4gasol, is dispatched. Node N4, another base/intermediate plant node, follows a similar pattern. Finally, at node N2, peaking plant is not dispatched at base load, but is dispatched in peak periods.

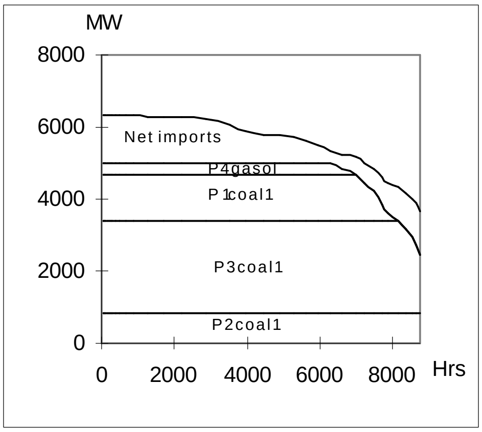
The augmentation of the transmission system affects both the timing of dispatch of various plants and the amount of power produced by plants at all nodes in the network. At node N4, the total supply increases in all periods and the mix in supply by individual generators changes. For example, after augmentation, generator P10coal1 supplies electricity in all periods (as it did in Scenario 1), but the amount it supplies increases and P12gasol only supplies after augmentation. The effect on generation at nodes directly effected by the link is also seen at node N1. Here the node becomes a net importer in all time periods — while in Scenario 1 it was a net importer at peak loads and a net exporter at base loads — drawing from the increased output of node N4. As discussed earlier, augmentation also affects nodes that are not directly tied to the link. For example after augmentation, node N2 still acts as a peaking plant node, but it is dispatched later, and supplies less electricity than it did in Scenario 1.

Figure 5.6: Merit order for plant dispatch, various scenarios

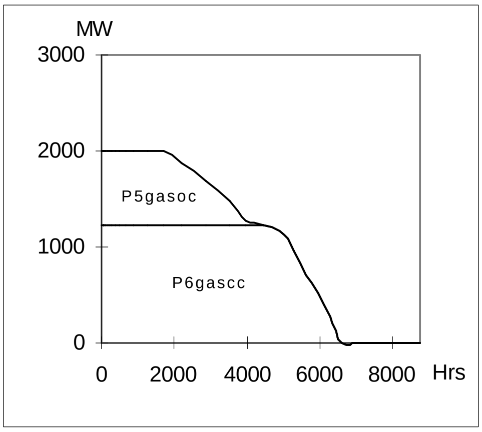
Scenario 1 — N1



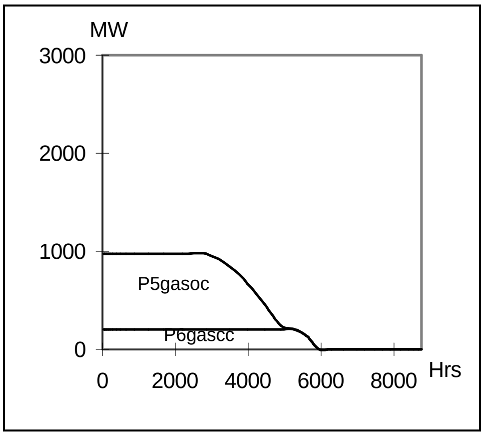
Scenario 2 — N1



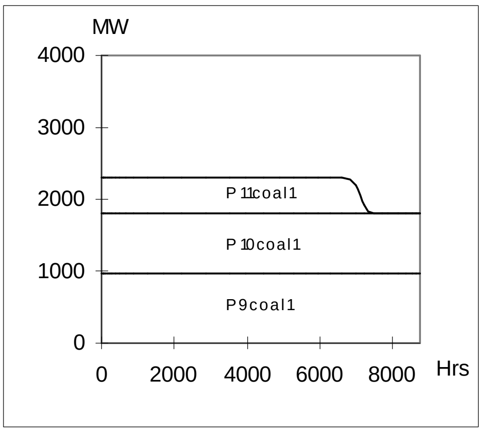
Scenario 1 — N2



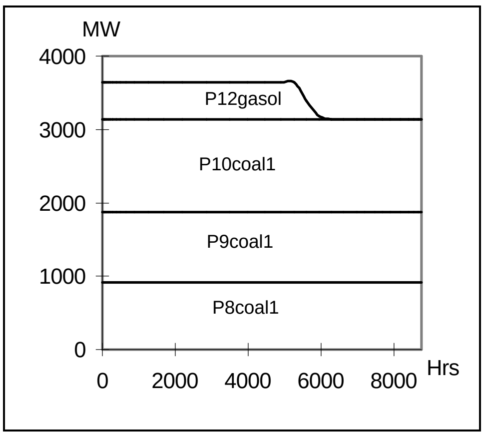
Scenario 2 — N2



Scenario 1 — N4



Scenario 2 — N4



The income earned by the transmission system is given by the merchandising surplus — this is the difference between the value of sales of electricity sold by the network (exports) and the value of sales purchased the network (imports). The source of this income is the shadow cost or imputed cost congestion from transmission lines that are constraining the network and the rent earned on transmission because marginal losses are higher than average losses.

Chao and Peck (1996) propose a system to allocate these rents to each transmission line, taking into account the network externality caused by Kirchoff's laws. This method takes into account that injecting power or withdrawing power at any node make a contribution to the whole systems marginal losses and any transmission constraints on links.

Although we have been able to replicate the method published by Chao and Peck (1996) using our modelling framework, we have not been able to replicate it for the example presented here. We suspect that there may be an intertemporal dimension introduced here because our example has 34 load periods which are interdependent via generation. In the Chao and Peck (1996) approach, the difference between nodal prices is decomposed into three components, representing contributions to system congestion costs, marginal transmission losses and the increase in energy purchased because energy losses.

5.10 Conclusion and further research

The model presented here provides insights into economic issues arising in electricity markets. It has integrated demand, transmission and generation into a single model to simulate the economically efficient operation of an electricity market.

The framework could be developed to further explore pricing issues in electricity markets. For example, introducing transmission capacity along each node as a variable, including its annualised fixed cost in the objective function. This would make transmission capacity along each node endogenous in the model, thereby allowing for simultaneous optimisation of demand, transmission capacity and generation.

Other examples are to extend to a multi-year model to evaluate long term dynamic effects on the market, such as the timing of transmission and generation augmentation, or investigate pricing rules to determine transmission fees along each link that are consistent with an economically efficient market, taking into account the network externality. This is an extension of the research by Chao and Peck (1996).

Table 5.3: Income earned by the whole transmission system in each load block ($m)

		Scenario 1			*Scenario 2*	
Load block	*Total*	*Congestion*	*Losses*	*Total*	*Congestion*	*Losses*
B1	0.74	0.11	0.63	1.06	0	1.06
B2	1.51	1.32	0.19	0.33	0	0.33
B3	1.98	1.65	0.33	0.57	0	0.57
B4	0.43	0	0.43	0.73	0	0.73
B5	0.74	0	0.74	1.24	0	1.24
B6	0.74	0.23	0.51	0.86	0	0.86
B7	0.76	0	0.76	1.28	0	1.28
B8	8.76	7.83	0.93	1.63	0	1.63
B9	0.94	0	0.94	1.57	0	1.57
B10	1.24	0	1.24	2.07	0	2.07
B11	1.52	0	1.52	2.52	0	2.52
B12	2.34	0	2.34	3.89	0	3.89
B13	1.97	0	1.97	3.27	0	3.27
B14	11.6	9.59	2	3.49	0	3.49
B15	2.58	0	2.58	4.46	0	4.46
B16	2.42	0	2.42	4.29	0	4.29
B17	13.65	11.94	1.71	3.24	0	3.24
B18	7.44	6.11	1.33	2.51	0	2.51
B19	4.53	3.4	1.13	2.13	0	2.13
B20	3.73	2.81	0.92	1.58	0	1.58
B21	3.37	2.55	0.82	1.26	0	1.26
B22	3.31	2.51	0.8	1.12	0	1.12
B23	3.2	2.43	0.77	0.98	0	0.98
B24	3.19	2.41	0.77	0.81	0	0.81
B25	0.64	0	0.64	0.83	0	0.83
B26	0.31	0	0.31	0.48	0	0.48
B27	0.35	0	0.35	0.63	0	0.63
B28	0.26	0	0.26	0.47	0	0.47
B29	0.2	0	0.2	0.45	0	0.45
B30	0.26	0	0.26	0.58	0	0.58
B31	0.2	0	0.2	0.45	0	0.45
B32	0.14	0	0.14	0.32	0	0.32
B33	0.1	0	0.1	0.24	0	0.24
B34	0.07	0	0.07	0.18	0	0.18
Total	85.22	54.89	30.31	51.52	0	51.52

Appendix A: GAMS code for the model

```
$offsymlist offsymxref
OPTIONS DECIMALS = 5;
OPTIONS LIMCOL =0;
OPTIONS LIMROW =0;
*OPTIONS SOLPRINT = OFF;
OPTIONS NLP = MINOS5;
OPTIONS SYSOUT = OFF;
OPTIONS ITERLIM = 20000;
OPTIONS RESLIM = 8000;

SETS
B LOAD BLOCKS
  / B1 * B34 /
N NODES
 / N1 * N4 /;
ALIAS (B,BP), (N,NP);

SETS
GR(N) NODES WHERE THERE IS GENERATION
  / N1, N2, N4  /

P GENERATING PLANTS
  / P1COAL1, P2COAL1, P3COAL1, P4GASOL, P5GASOC, P6GASCC,
    P7DIST, P8COAL1, P9COAL1, P10COAL1, P11COAL1, P12GASOL/
NG(N,P) THE PLANTS AT EACH NODE
  /N1.(P1COAL1, P2COAL1, P3COAL1, P4GASOL)
   N2.(P5GASOC, P6GASCC)
   N3.(P7DIST)
   N4.(P8COAL1, P9COAL1, P10COAL1, P11COAL1, P12GASOL)/
D(N) NODES WHERE THERE IS DEMAND
  / N1, N3 /
LK(N,NP) LINK BETWEEN EACH NODE IN THE NETWORK
  /N1.(N2, N3, N4)
   N2.(N1, N3)
   N3.(N1, N2, N4)
   N4.(N1, N3)/
NT(N) NODES THAT ARE NOT NODE N4
 /N1, N2, N3/


LABELS NAMES TO IDENTIFY PLANT DATA
  / UNITS    NO OF UNITS AT EACH PLANT
    AVAIL    AVAILABILITY OF EACH PLANT
    GENMIN   MINIMUM CAPACITY OF GENERATORS
    GENMAX   MAXIMUM CAPACITY OF GENERATORS
    FUELCOST FUELCOSTS ($ per MWh)
    CAPCOST  CAPITAL COST ($mill PER MW)
    LIFE     LIFE OF UNITS (years)/;

* ELEMENTS UNDERLYING DEMAND AT EACH NODE
TABLE DMD(B,N) DATA FOR LOAD AT EACH NODE IN EACH BLOCK (MW)
       N1       N3
B1     6500     2909.29
B2     6400     2814.83
B3     6300     2795.82
B4     6200     2785.80
B5     6100     2761.74
B6     6000     2724.57
B7     5900     2696.79
```

```
B8     5800     2644.10
B9     5700     2646.52
B10    5600     2617.59
B11    5500     2609.79
B12    5400     2600.58
B13    5300     2541.84
B14    5200     2472.71
B15    5100     2485.65
B16    5000     2436.29
B17    4900     2370.75
B18    4800     2321.46
B19    4700     2303.01
B20    4600     2247.04
B21    4500     2188.80
B22    4400     2149.72
B23    4300     2074.14
B24    4200     2029.16
B25    4100     1979.27
B26    4000     1912.78
B27    3900     1858.47
B28    3800     1794.04
B29    3700     1742.41
B30    3600     1676.24
B31    3500     1633.05
B32    3400     1583.99
B33    3300     1538.78
B34    3200     1463.29   ;

TABLE ENERGY(B,N) DATA FOR ENERGY AT EACH NODE IN EACH BLOCK (GWh)
       N1          N3
B1     246.42      107.45
B2     84.02       36.69
B3     151.70      66.82
B4     203.48      90.79
B5     360.99      162.01
B6     275.79      124.31
B7     438.85      199.21
B8     609.98      275.74
B9     624.37      287.49
B10    920.31      426.53
B11    1241.37     584.02
B12    2107.88     1005.71
B13    2195.53     1043.74
B14    2702.30     1273.22
B15    3400.93     1641.72
B16    3249.15     1566.77
B17    2432.17     1164.07
B18    2254.98     1079.34
B19    2094.40     1015.72
B20    1716.95     829.93
B21    1551.76     746.60
B22    1509.13     728.60
B23    1454.50     693.97
B24    1458.99     696.56
B25    1497.75     713.83
B26    854.03      403.11
B27    1114.64     524.91
B28    820.00      381.98
B29    798.85      370.99
```

```
B30    1007.68    462.51
B31    772.28     354.80
B32    532.17     244.34
B33    393.11     180.53
B34    294.14     133.52     ;

PARAMETERS
HOURS(B) NUMBER OF HOURS IN EACH LOAD BLOCK
/ B1      36.935
  B2      13.036
  B3      23.899
  B4      32.589
  B5      58.661
  B6      45.625
  B7      73.869
  B8     104.286
  B9     108.631
  B10    162.946
  B11    223.780
  B12    386.726
  B13    410.625
  B14    514.911
  B15    660.476
  B16    643.095
  B17    491.012
  B18    464.940
  B19    441.042
  B20    369.345
  B21    341.101
  B22    338.929
  B23    334.583
  B24    343.274
  B25    360.655
  B26    210.744
  B27    282.440
  B28    212.917
  B29    212.917
  B30    275.923
  B31    217.262
  B32    154.256
  B33    117.321
  B34     91.250 /;

PARAMETERS
PRI(B) BASE PRICE (cent per kWh)
/ B1     6.55
  B2     6.46
  B3     6.42
  B4     6.28
  B5     6.23
  B6     6.00
  B7     5.92
  B8     5.84
  B9     5.76
  B10    5.58
  B11    5.43
  B12    5.35
  B13    5.15
  B14    4.85
  B15    4.43
```

```
  B16    4.23
  B17    4.15
  B18    4.07
  B19    4.06
  B20    3.97
  B21    3.66
  B22    3.50
  B23    3.28
  B24    2.85
  B25    2.65
  B26    2.45
  B27    1.87
  B28    1.79
  B29    1.62
  B30    1.54
  B31    1.46
  B32    1.38
  B33    1.21
  B34    0.98 /;
PARAMETERS
 PRICE(N,B) PRICE AT EACH NODE IN EACH LOADBLOCK (cent per kwh);
 PRICE('N1',B) = 1.75*PRI(B);
 PRICE('N3',B) = 2.5*PRI(B);
PARAMETERS
  BETA(N)  PRICE ELASTICITIES OF DEMANDS IN EACH BLOCK AT EACH NODE
  IBETA(N,B) SLOPE IN INVERSE DEMAND FUNCTION IN EACH BLOCK AT EACH NODE
  ALPHA(N,B) CONSTANTS FOR INVERSE DEMAND FUNCTION IN EACH BLOCK AT EACH
NODE ($M PER PWH);
    BETA(N) $d(n)  = -0.3;
    IBETA(N,B) $d(n) = 1/BETA(N)*PRICE(N,B)*10/(ENERGY(B,N)/1000);
    ALPHA(N,B) $d(n) = PRICE(N,B)*10-IBETA(N,B)*ENERGY(B,N)/1000;
```

```
* ELEMENTS UNDERLYING SUPPLY AT EACH NODE
TABLE PDATA(P, LABELS) DATA FOR EACH OF THE GENERATING PLANTS
        UNITS AVAIL  GENMIN  GENMAX  FUELCOST  CAPCOST  LIFE
*                    MW      MW      $-MWh     $M-MW     years
P1COAL1     2    1   286     635     14.8      1.2        30
P2COAL1     3    1   110     287     14.0      1.4        30
P3COAL1     4    1   176     635     14.3      1.3        30
P4GASOL     2    1   200     250     18.5      1.2        30
P5GASOC     6    1   0       999     32        0.5        30
P6GASCC     6    1   0       999     23.5      0.85       25
P7DIST      4    1   0       999     150       0.3        30
P8COAL1     2    1   275     634     12.1      1.45       30
P9COAL1     2    1   227     480     13.0      1.3        30
P10COAL1    2    1   250     634     12.2      1.4        30
P11COAL1    2    1   205     445     14.8      1.25       30
P12GASOL    2    1   200     250     18.5      0.8        30;

SCALARS
  RHO INTEREST RATE / 0.08 /
  PRR PEAK RESERVE REQUIREMENT / 0.14 /

PARAMETERS
  PLANTCOST(P) FIXED ($M per GW) COSTS
  OPCOST(P,B) VARIABLE ($M per GW) COSTS;
  PLANTCOST(P) = (RHO/(1-(1+RHO)**(-PDATA(P,'LIFE'))))
                    *PDATA(P,'CAPCOST')*1000;
  OPCOST(P,B) = (PDATA(P,'FUELCOST'))/1000*HOURS(B);

* DISPLAY OPCOST, PLANTCOST;

* ELEMENTS UNDERLYING THE NETWORK
PARAMETERS
  R(N,NP) RESISTANCE ALONG LINE FROM NODE N TO NODE NP (OHMS)
  X(N,NP) INDUCTANCE ALONG LINE FROM NODE N TO NODE NP (OHMS)
  Y(N,NP) PARAMENTER IN KIRCHOFF EQUATON
  G(N,NP) PARAMETER IN KIRCHOFF EQUATION;

TABLE V(N,NP) VOLTAGE AMPLITUDE NODE N NODE NP (KV)
         N1   N2   N3   N4
N1       0    330  500  330
N2       330  0    330  0
N3       500  330  0    330
N4       330  0    330  0;

TABLE NUMBER(N,NP) NUMBER OF POWERLINES BETWEEN NODES IN THE NETWORK
         N1  N2   N3   N4
N1       0   6    4    2
N2       6   0    5    0
N3       4   5    0    2
N4       2   0    2    0;

TABLE DIST(N,NP) DISTANCE BETWEEN NODES IN THE NETWORK (KM)
         N1  N2   N3   N4
N1       0   150  375  150
N2       150  0   450  0
N3       375  450 0    400
N4       150  0   400  0;
```

```
TABLE RES(N,NP) RESISTANCE PER KM ALONG LINE FROM NODE N TO NODE NP (OHMS
per KM)
        N1    N2   N3    N4
N1      0     0.03 0.025 0.03
N2      0.03  0    0.03  0
N3      0.025 0.03 0     0.03
N4      0.03  0    0.03  0;

TABLE IMPED(N,NP) IMPEDANCE PER KM OF ALONG LINE FROM NODE N TO NODE NP
(OHMS per KM)
         N1   N2   N3   N4
N1       0    0.3  0.25 0.3
N2       0.3  0    0.3  0
N3       0.25 0.3  0    0.3
N4       0.3  0    0.3  0;

TABLE GRIDCAP(N,NP) ESTIMATED GRID CAPACITY IN THE NETWORK (MW)
         N1   N2   N3   N4
N1       0    3000 1500 1500
N2       3000 0    3000 0
N3       1500 3000 0    2000
N4       1500 0    2000 0 ;

X(N,NP)$lk(n,np) = IMPED(N,NP)*DIST(N,NP);
R(N,NP)$lk(n,np) = RES(N,NP)*DIST(N,NP);
Y(N,NP)$lk(n,np) = X(N,NP)/(SQR(R(N,NP))+SQR(X(N,NP)));
G(N,NP)$lk(n,np) = R(N,NP)/(SQR(R(N,NP))+SQR(X(N,NP)));

* THE MODEL

POSITIVE VARIABLES
  QS(N,B) ELECTRICTY SUPPLIED AT NODE N IN LOAD BLOCK B   (GW)
  QD(N,B) ELECTRICITY DEMANDED AT NODE N IN LOAD BLOCK B  (PWH)
  QGO(P,B) OUTPUT OF PLANT P IN LOAD BLOCK B (GW)
  QGC(P) OPERATING CAPACITY OF EACH PLANT P (GW)

FREE VARIABLES
  NSR NET SOCIAL WELFARE ($M)
  QP(N,NP,B) QUANTITY OF POWER FLOW AT EACH NODE IN EACH TIME BLOCK (GW)
  THETA(N,B) VOLTAGE phase ANGLES (RADIANS);

EQUATIONS
  OBJ NET SOCIAL WELFARE ($M)
  GENBAL(P,B) CAPACITY-OUTPUT BALANCE AT EACH GENERATOR IN EACH LOAD
BLOCK(GW)
  GMAXCAP(P) MAXIMUM CAPACITY CONSTRAINT FOR EACH PLANT(GW)
  NODEBAL(N,B) SUPPLY BALANCE AT EACH GENERATING NODE(GW)
  POWER(N,NP,B) POWER FLOW AT EACH NODE (GW)
  FLOWBAL(N,B) POWER FLOW BALANCE(GW)
  FLOWMAX(N,NP,B) MAXIMUM FLOW BETWEEN TWO NODES FOR EACH LOAD BLOCK(GW);


*objective function
OBJ..
  NSR =E= SUM((N,B)$d(n),(ALPHA(N,B)*QD(N,B)+0.5*IBETA(N,B)*(QD(N,B)**2)))
        - SUM((P,B),OPCOST(P,B)*QGO(P,B))
        - SUM((P),PLANTCOST(P)*QGC(P));

* IF THE PLANT IS SWITCHED ON, THE AMOUNT SUPPLIED IN EACH LOAD BLOCK
EQUALS THE AMOUNT SWITCHED ON
GENBAL(P,B)..
  QGO(P,B) =L= QGC(P)*PDATA(P,'AVAIL');

* THE OPERTING CAPACITY IS LESS THE THE UPPER BOUND ON GENERATION
GMAXCAP(P)..
```

```
  QGC(P) =L= PDATA(P,'UNITS')*PDATA(P,'GENMAX')/1000;

* THE NODE SUPPLY = THE TOTAL OUTPUT OF ALL GENERATORS AT THE NODE
NODEBAL(N,B)$GR(N)..
  QS(N,B) =L= SUM(P$(NG(N,P)), QGO(P,B));

* GETTING AN EQUATION FOR POWER
POWER(N,NP,B)$LK(N,NP)..
  QP(N,NP,B)*1000
=E= G(N,NP)*(V(N,NP)**2-V(N,NP)*V(NP,N))
+Y(N,NP)*V(N,NP)*V(NP,N)*THETA(N,B)$NT(N)
-Y(N,NP)*V(N,NP)*V(NP,N)*THETA(NP,B)$NT(NP)
+0.5*G(N,NP)*V(N,NP)*V(NP,N)*(THETA(N,B)$NT(N))**2
-0.5*G(N,NP)*V(N,NP)*V(NP,N)*2*THETA(N,B)$NT(N)*THETA(NP,B)$NT(NP)
+0.5*G(N,NP)*V(N,NP)*V(NP,N)*(THETA(NP,B)$NT(NP))**2;

* NODE DEMAND = OWN NODE SUPPLY - POWER FLOW FROM AT NODE FROM OTHER NODES
* A POSITIVE POWER FLOW AT THE NODE IS A FLOW AWAY FROM THE NODE
* A NEGATIVE POWER FLOW AT THE NODE IS A FLOW INTO THE NODE
FLOWBAL(N,B)..
  QD(N,B)$d(n)*(1000/HOURS(B))
         =E=  QS(N,B)$GR(N)
                    - SUM(NP$lk(N,NP), NUMBER(N,NP)*QP(N,NP,B));

* NET FLOW ALONG LINK < MAXIMUM FLOW ALONG LINK
FLOWMAX(N,NP,B)$LK(N,NP)..
  NUMBER(N,NP)*QP(N,NP,B)  =L= GRIDCAP(N,NP)/1000;

MODEL NETWORK /ALL/ ;

NETWORK.OPTFILE = 1 ;
* ABORT $(ALPHA("N1","B1") GT 0) "END";
SOLVE NETWORK MAXIMISING NSR USING NLP;

DISPLAY QD.L, QS.L, QGO.L, QGC.L, QP.L;
DISPLAY QD.M, QS.M, QGO.M, QGC.M, QP.M;
DISPLAY THETA.L;
```

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PANEL SESSION 2

Invited paper 6

Contracts and electricity pool prices

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6.1 Introduction

In recent years, the electricity sector has been transformed from a vertically integrated monopoly to a disintegrated one that is capable of generating competition in both generation and retailing. This change has been well established in England and Wales and now in Victoria and New South Wales. South Australia and Queensland face similar reforms with an eventual formation of the National Electricity Market (NEM).

The change in the structure of electricity production has come about because of the establishment of a spot or pool market for electricity generation. This pool is characterised by generators making half-hourly bids of generation and a price schedule and a pool operator using these bids as the basis for a dispatch schedule. Generators then receive the system marginal price (SMP) on all units dispatched. The SMP is the highest price paid for any unit dispatched. Economists have begun to model this pool market behaviour as either an equilibrium in supply functions (Green and Newbery 1990) or, alternatively, as a multi-unit simultaneous auction (von der Fehr and Harbord 1992). These analyses have shown that pool markets may not produce competitive outcomes if there are a small number of dominant generators. Hence, pool prices may be substantially above marginal cost.

Side by side with pool markets are both long and short-term contract markets for electricity. By writing contracts, generators and retailers can share risks associated with a fluctuating pool price. But concern has been raised that the imperfect competition of pool markets will simply translate into market power being exercised in contract markets. Therefore, the existence of a contract market may allow generators further leverage over retailers.

The purpose of this paper is to explore the linkages between pool and contract market power. Some of these issues have been considered by previous researchers. Von der Fehr and Harbord (1992) model the pool as a multi-unit auction and demonstrate that contracts give generators a strategic advantage in the pool market by allowing them to commit to supply greater quantities during peak demand periods. However, their model suffers from the disadvantage that the contract prices are held fixed when in reality they will adjust over time depending on potential pool market behaviour. On the other hand, Green (1996) appropriately looks at the endogenous formation of both pool and contract prices in a supply function model. His analysis in many ways mirrors some of the conclusions below. However, his reliance on the complex, albeit descriptively accurate, supply function model makes it difficult to analyse how alterations in the cost structure of generation influence the exercise of market power.

In this paper we use a Cournot model of pool market behaviour that lies at one extreme of the supply function models — where the ability of generators to influence market power by making quantity commitments is greatest.[1] In addition, we model both generators and retailers as risk neutral and hence, there are no risk sharing benefits in signing long-term contracts. Nonetheless, we are able to show that contracts are signed and, in contrast to the concerns of some, make electricity markets more, not less, competitive. The existence of contracts in some instances improves efficiency directly by affording more efficient generators a greater market share. We then turn to consider the effect of the contract market on entry decisions. A final section concludes with remarks about the role of contracts in investment.

6.2 An overview of electricity contracts

While the analysis to follow will eliminate risk sharing aspects of contracting, these are the concerns that provide a rationale for the existence of contract markets. Therefore, it is worth reflecting, initially, on the role of long-term contracts in this regard.[2]

To generators and retailers the greatest risk posed by electricity pools is the financial consequences of fluctuating pool prices. Pool prices will vary each half hour and will be determined by the balance of supply and demand. Whilst the level of demand can be estimated, the availability of generation capacity in the market is less predictable. Generators themselves will choose how much electricity they will offer to produce. The power station with the highest marginal bid that is operating at any point in time (and the price they require to operate) determines the pool price.

In addition, availability is also affected by forced/partial outages which are not anticipated. These uncertainties about availability consequently affect the stability of pool prices in the short, medium and long-term. Therefore, generators and retailers may wish to cover themselves for this pool price risk by taking out an option contract (which are known in the United Kingdom (UK) as Contracts for Differences or CfDs).

---

1 Grant and Quiggin (1996) demonstrate that Cournot outcomes naturally result in supply function models when capital pre-commitments are relatively inflexible, as in electricity generation investment.

2 A short-term day ahead contract market is also proposed for the NEM. This market is not the focus of this paper.

These contracts are purely *financial* transactions. When these option contracts are set alongside *physical* sales or purchases from the pool provide insurance against excessive fluctuations in the pool price. These contracts are used in the UK, Victoria, New South Wales and a similar contract market will operate in the NEM. For example, vesting contracts are simply a financial hedge with a range of cross-subsidies added into the contract price. The nature of these contracts is described below.

Contract components

All contracts types have two common elements: a strike price and a quantity. However, many are more complex, with multiple strike prices for different times of the day or periods of the year and contract quantities which may be 'sculpted' over the course of the year. Further, some contracts can only be 'called' during certain periods, such as peak times.

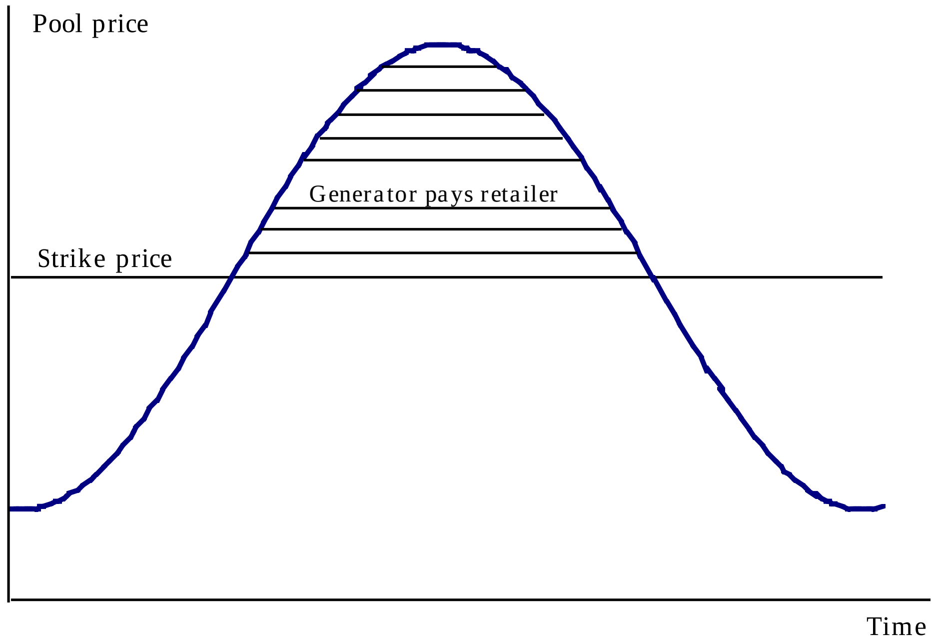
The key components of a contract are listed and briefly described below:

1. *one-way/two way options*: the contract may be called by the holder (retailer) or seller (generator) of the option, depending upon how the option is defined;
2. *firm/non-firm capacity*: the contract may be firm or related to the availability of particular generating sets;
3. *strike price*: this will set the price level at which the contract can be called. It can be varied by time or day. It can also be escalated from year to year;
4. *maximum capacity*: the amount of capacity for which the contract can be called can be sculpted by time of day or year to match a purchaser's load shape;
5. *maximum and minimum takes*: safeguards can be set against the contract being called too much or too little by constraining the number of takes;
6. *option constraint*: the hours in which the option can be called, whether or not the strike price is below pool price, can be limited; and
7. *length of contract*: this determines the overall commitment to the contract terms.

Basic contract types

There are essentially two forms of these contracts: *one-way* and *two-way*. One-way contracts establish a ceiling pool price (the strike price), as illustrated in figure 6.1. If the price is below the ceiling price retailers pay the pool price, if it is above the ceiling price retailers still pay the pool price but are compensated by the generator for the difference between the ceiling and pool price.

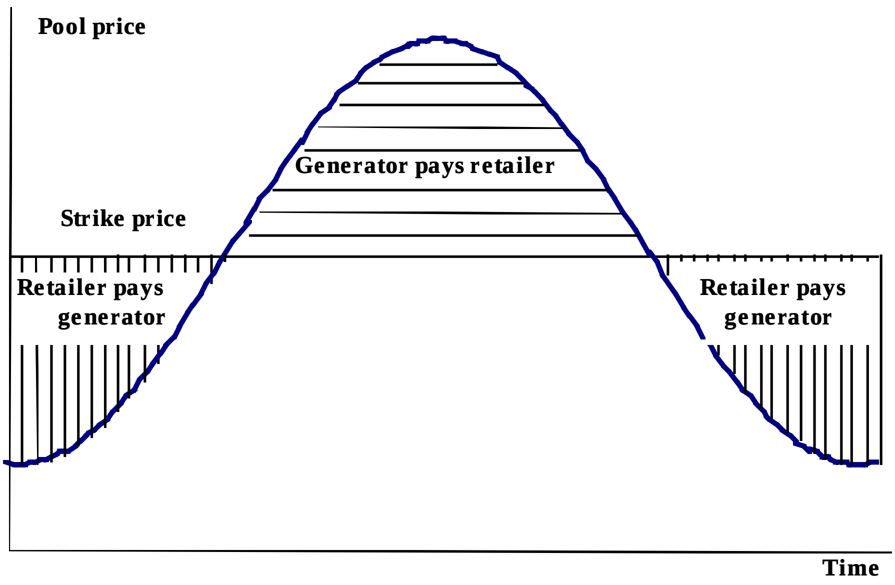
Figure 6.1 One-way contracts



Generators sell the contracts to distributors for a fixed option fee. If both contracting parties are risk-neutral, the value of the option fee would be equal to the net present value of the difference between expected pool purchase costs and purchase costs under the contract (net of the option fee). That is, the net present value of the expected pool price and the contract price is the same. Since the expected pool price is used to determine the amount that a buyer would pay for the option fee, it is important to redirect the future pool price path as accurately as possible to minimise contract trading costs.

Two-way contracts work in a similar way to one-way contracts. The difference is that a two-way contract establishes a firm price for both generator and retailer (see figure 6.2). Two-way contracts for differences are like forward contracts — retailers and generators essentially have agreed to buy/sell electricity for a fixed price over a fixed period in the future. Therefore, two-way contracts are not normally associated with option fees. Under a two-way contract, if the pool price rises above the strike price, generators compensate retailers for the difference. But if pool price falls below the strike price, then retailers compensate generators for the difference. The net present value of the strike price should approximate the net present value of the pool price.

Figure 6.2 Two-way contracts



Generally, one-way contracts are the preferred form of cover against infrequent events, such as pool prices moving above $300/MWh. Thus, the generator bears the risk if the pool price below the strike price; they will not be compensated for downward shocks.

Two-way contracts are preferred when broader coverage is required. In these events the main advantage of the two-way contract is that it reduces *generator* exposure to revenue risk when pool prices fall below contract strike price. Under a one-way contract generators are exposed to this risk. To the extent that generators will be risk adverse they will prefer two-way to one-way contracts. This has happened in Victoria. Two-way contracts are generally used to cover base load demand and part of their intermediate demand. One-way contracts are used for intermediate and peak demand.

While the role of one-way contracts is to hedge against the pool price risk borne by retailers, two-way contracts involve both retailers and generators sharing risk and, as will be demonstrated below, an additional strategic advantage to generators. As such, this paper will focus exclusively on two-way contracts for differences.

6.3 The strategic effects of contracts

We begin by considering a simple model of Cournot duopoly competition. As mentioned earlier, our decision to focus on the Cournot case is to demonstrate most clearly the existence of strategic effects to contracting. This allows us to use a simple framework to explore the comparative statics associated with such contracting (cf: Green 1996). The restrictive assumptions we employ are for ease of exposition and can be generalised quite easily.

There are two generators in the industry each subscripted by $i = 1, 2$. Inverse industry demand for electricity is a linear function $p = A - b(q_1 + q_2)$. This is simply the inverse load duration curve for a particular time period. It represents the choices of retailers and customers which are unmodelled in this paper. While industry demand is stochastic in practice, here we will ignore this possibility — this is a reasonable restriction given our assumption the generators and retailers are risk neutral. Generator production costs are linear with $C_i(q_i) = c_i q_i$, where we assume initially that $c_1 = c_2 = c$. There are potentially capacity restrictions on generators. Consideration of these will be left to a later section. Finally, we assume that $A > c_i$ for all i so that each firm's output is positive in equilibrium.

The game between generators proceeds in two stages. In the first stage, generators can pre-emptively contract with retailers. That is, they each choose, x_i, their contracted quantity, with the strike price, z, a function of their competition in contracting. In the second, spot market competition in the pool occurs. As will be shown, what occurs in the latter stage is influenced by the first. This is because both generators and retailers have rational expectations regarding what price will result in the pool in stage two. Indeed, given the assumption of risk-neutrality, no retailer will sign a contract with a strike price less than the expected spot price and generators will, in equilibrium, not find it advantageous to offer lower contract prices than expected spot prices. Therefore, agents will expect that $z = p$.

We will analyse the model by working backwards considering stage two pool market behaviour contingent on any feasible contract set signed and then looking at contract market behaviour in which all parties expected the predicted stage two behaviour.

Stage two: the spot market

Suppose that both generators have signed contracts for amounts (x_1, x_2) in stage one. A generator's profits in stage two will then be:

$$_i = p(q_i - x_i) + zx_i - cq_i \,.$$

Given our Cournot assumption, each generator chooses q_i to maximise this function, holding the quantities of all other generators as given. The first-order condition for this maximisation problem is:

$$\frac{\ \ _i}{\ q_i} = -b(q_i - x_i) + p - c = 0 \Rightarrow q_i = \frac{A - bq_j + bx_i - c}{2b} \,.$$

This equation defines the reaction function for generator 1. The key feature to note about this function is that it is increasing in own level of contract cover and only depends on the level of contract cover of the other generator through that generator’s quantity. The intuition for this relationship can be best demonstrated graphically. Figure 6.3 depicts the inverse demand curve facing generator 1 for a given q_2. It also depicts the marginal revenue curve facing that firm when it has no contract cover. However, if it has x_1 units of contract cover at a strike price of z, this effectively flattens its inverse demand and marginal revenue curves over this range. While for quantities beyond x_1 the demand curve continues as before, the origin of the downward sloping portion of the marginal revenue curve is x_1 rather than zero. For a constant marginal cost, the quantity at which marginal revenue equals marginal cost is greater when the generator has signed a forward contract for some quantity. This occurs regardless of the quantity chosen by the other generator, hence, pushing the reaction curve upwards.

It should be noted that when a generator contracts some output, regardless of the strike price on that contract, it should bid that contracted amount into the pool at marginal cost. This ensures that when the pool price is above marginal cost, the generators contracted amount is dispatched. If it were not dispatched it would be effectively forced to act financially as if it had bought the unproduced portion of the contract at pool prices. Thus, if individual demand facing a generator where relatively low, as in figure 6.4, it may find itself not producing its full contracted amount. While this is optimal if the pool price is below marginal (or avoidable) cost, the generator is strictly better producing this quantity if the pool price is above marginal cost. Note that a firm whose output is entirely contracted, that is with $x_i = q_i$, ends up with price equal to marginal cost. This mirrors a result demonstrated by Green (1996) for restricted supply function equilibria.

Figure 6.3 Effect of contracts on pool quantities

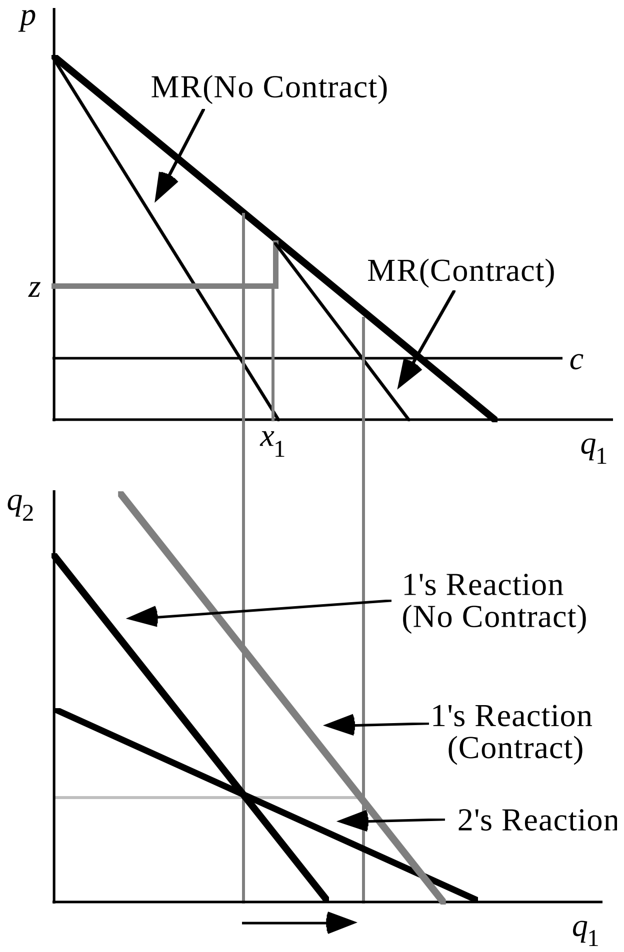
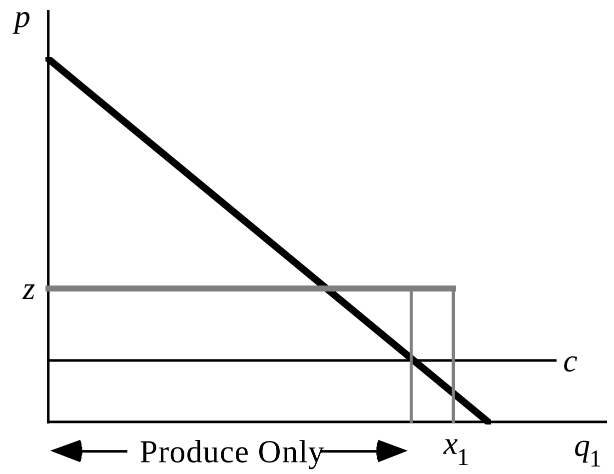


Figure 6.4 Excessive contract cover



Solving out for the unique equilibrium in the stage two sub-game, we have:

$$q_i = \tfrac{1}{3}\left(\tfrac{1}{b}(A-c) + 2x_i - x_j\right) \text{ for all } i \text{ and } p = \tfrac{1}{3}\left(A - b(x_1 + x_2) + 2c\right).$$

Observe that price is lower when the sum of contract cover is greater. Moreover, whenever one generator increases its contract cover relative to the other, its quantity sold is greater while the quantity sold by its rival is lower. As depicted in figure 6.3, the assumption of Cournot competition means that each generator's quantity choice is decreasing in those of its rivals (that is, they are strategic substitutes). Greater individual contract cover raises the returns to having higher quantities in the pool, it raises a given generator's output but also results in reduced output by other generators and a lower pool price overall.

Therefore, by encouraging generators to bid a greater quantity into the pool at any given time, contracts have a *strategic effect* on the equilibrium in stage two. Note that in Bertrand competition the pool price equals marginal cost always so that the amount of contract cover does not have this strategic effect. It is only when generators can make quantity commitments (even partly) that the strategic implications of contracting are realised.

Stage one contract market

Each generator and retailer realises that contracts have effects on pool prices. For each generator, greater contract cover raises their incentives to bid larger quantities in the pool and forces others to reduce their quantities, all other things being equal. The lower pool prices will mean that retailers will demand a lower strike price for any contract signed, however. The question is, what will happen when each generator competes for these contracts?

As noted earlier, in equilibrium $z = p$, that is, $z = \tfrac{1}{3}\left(A - b(x_1 + x_2) + 2c\right)$. Each generator, therefore, anticipates the following profit in stage two:

$${}_i = (p-c)q_i = \tfrac{1}{9b}\left(A - b(x_i + x_j) - c\right)\left(A + b(2x_i - x_j) - c\right).$$

Once again, using this payoff, generators choose their level of contract cover, holding the contract choices (but not the ultimate spot market choices) of the other generator as given. In general terms, the marginal return to contracting is:

$$\frac{{}_i}{x_i} = \underbrace{\tfrac{dq_i}{dx_i}\left(p - b(q_i - x_i) - c\right)}_{=0} - \underbrace{\tfrac{dq_j}{dx_i}bq_i}_{\text{Strategic Effect}}.$$

The first term is zero by the envelope theorem. Under risk neutrality, there is no direct cost or demand advantage from contracting. Therefore, the effect is purely a strategic one (a 'top dog' strategy in Fudenberg and Tirole's (1984) terminology). This is positive for, as noted earlier, increased contracting raises own output in the spot market reducing the quantity bid by the rival generator.

Considering our specific model, the first order condition for the profit maximising choice of contract level is:

$$\frac{\partial \pi_i}{\partial x_i} = -\tfrac{1}{9}\left(A + b\left(2x_i - x_j\right) - c\right) + \tfrac{2}{9}\left(A - b\left(x_i + x_j\right) - c\right) = 0$$

which, in the unique symmetric sub-game perfect equilibrium, yields:

$$x_1 = x_2 = \frac{A-c}{5b} \text{ and } z = \frac{A+4c}{5}.$$

Observe that the resulting level of output (both contracted and spot) for a generator is:

$$q_1 = q_2 = \frac{2(A-c)}{5b},$$

twice the contracted level. So in this specific example, generators contract half of their output in equilibrium.

What is the impact of contracting upon price? To conduct this experiment, observed that if no contracts were allowed, then:

$$p = \frac{A+2c}{3} \text{ and } q_1 = q_2 = \frac{A-c}{3b}.$$

Therefore, it is easy to see that by allowing for contracting, price is lower and output is greater. So while each generator has a strategic benefit from pre-emptive contracting, in equilibrium this possibility harms their profits. Each would prefer to commit not to contract, but in a similar vein to the Prisoner's Dilemma, each chooses to contract a positive amount imposing a negative effect on the other's profits (see Allaz and Villa 1993 for extensions of this idea).

6.4 Asymmetries between generators

The previous analysis considered the role of contracts in a symmetric environment. While the strategic role of contracts and its competitive benefits continue to hold with non-linear demands and costs, one cannot analyse whether more efficient generators use contracts relatively more or less than less efficient ones in a symmetric environment. Therefore, in this section, we extend our basic model to consider heterogeneous cost structures among generators.

Consider first a situation in which generators differ in their marginal costs, that is $c_1 > c_2$. In this case, the equilibrium is no longer symmetric. It is still unique, however, and has the solution:

$$x_1 = \frac{A - 3c_1 + 2c_2}{5b} \text{ and } x_2 = \frac{A - 3c_2 + 2c_1}{5b}$$

$$q_1 = \frac{2(A + 2c_2 - 3c_1)}{5b} \text{ and } q_2 = \frac{2(A + 2c_1 - 3c_2)}{5b}$$

$$z = p = \frac{A + 2(c_1 + c_2)}{5}$$

Note that even though $q_1 > q_2$, each generator continues to contract half of its output.

Without contracting, we would have:

$$p = \frac{A + c_1 + c_2}{3},\ q_1 = \frac{A + c_2 - 2c_1}{3b} \text{ and } q_2 = \frac{A + c_1 - 2c_2}{3b}$$

Once again, the output of both generators is higher and price lower when contracting is possible. One can also compare the market shares of generators when contracting is and is not allowed. Interestingly, with contracting, the market share of the more efficient plant is higher than the case where contracting is not possible.

These conclusions are not robust to alternative cost specifications. Suppose that $C_i(q_i) = c_i \frac{1}{2} q_i^2$. It is cumbersome but not difficult to show that while the results of section 6.3 continue to hold for this cost function, generators contract a third of their output in equilibrium but the market shares in the contracting as compared with the no contracting case are exactly the same. Nonetheless, as one increases the marginal costs of one generator, its output falls, the output of its rival rises, total industry output falls, contract levels fall and each firm continues to contract one third of its output.

This example of increasing marginal costs captures part of the technology of electricity generation. In reality, however, the capacity constraints on a generator are such that marginal cost is relatively flat for most output below a certain level at which it becomes very step (that is, the marginal cost curve is an inverted L-shape). Capacity constraints of this form are difficult to analyse. If both generators are expected to be constrained in a given period (that is, in periods of high demand), then neither one gains a strategic advantage from pre-emptive contracting as this does not reduce the quantity the other bids into the pool. On the other hand, in periods of low demand, both have strategic incentives similar to those analysed in this paper. Thus, one would expect the degree of contract cover to vary with the intensity of demand.

One can also ask whether large versus small generators have a greater incentive to contract, all other things equal. Assuming equal marginal costs, small generators are likely to be constrained more often. In a duopoly, this means that a large generator will have a reduced strategic incentive to contract as they cannot influence the quantity the small generator bids into the pool. In reality, when there is no duopoly, however, it is difficult to say whether large or small generators will have a greater incentive to pre-emptively contract.

6.5 Contracts and entry

The previous sections demonstrated that contracts have the effect of diminishing the overall price for electricity and, hence, the profits of individual generators. In a static setting, where there is no possibility of entry, this represents a welfare improvement through greater allocative efficiency in electricity. However, lower prices and industry profits make entry unattractive. While this would not be a concern in industries where entry can be smooth and entrants have considerable flexibility over the scale of production, in electricity, this is not a reasonable assumption. Entry will give rise to discrete changes and potential entrants will have to take account of larger changes in prices received.

Once again, we ask the question: what does the existence of a contract market have on pool prices? Newbery (1997) has analysed the interaction between contracts and entry deterrence in electricity markets. In a model in which only incumbent generators were able to sign contracts, he demonstrated that such contracts facilitated entry deterrence by committing generators to lower pool prices — below the level that would allow for entry. In contrast, we allow a potential entrant as well as incumbents to compete for pre-emptive contracts for differences. This seems reasonable as it will, potentially, be in retailers' interests to encourage entry.

We analyse this case as follows. Suppose that there are two incumbent generators, 1 and 2, as in section 6.3 who have symmetric marginal costs, c. In addition, suppose there are no capacity constraints. There is a potential entrant, 3, who has marginal cost of $\underline{c} \leq c$, but must incur a sunk entry cost of $F > 0$. It will, therefore, enter if its expected profits $_{3} \geq F$.

It is quite easy to demonstrate that entry profits are lower when there is a contract market compared with a situation in which such a market does not exist. Therefore, there exists a range of sunk costs, F, such that the entrant would choose to enter if there was no contract market but would enter otherwise. If this is the case, then the price that prevails when there is no contract market is $\frac{1}{4}(A+2c+\underline{c})$, as entry has occurred. However, when there is a contract market, entry does not occur so the price remains at its duopoly level, $\frac{1}{5}(A+4c)$. In this case, a contract market serves to lower electricity prices if, and only if, $A-c \geq 5(c-\underline{c})$, that is if the cost differential is small. For a large entrant cost advantage, if F is such that entry might be deterred by having a contract market, then the existence of contracts is potentially anti-competitive.[3]

6.6 Conclusions

This paper has demonstrated that contract markets can serve to make oligopolistic spot markets more competitive. Generators have a purely strategic incentive to sign forward contracts so as to raise their share of the overall electricity market. However, this option has a negative effect on the profits of other generators. Each is caught in the equivalent of a Prisoner's Dilemma motivating them to sign contracts when it is in their mutual interest to refrain from so doing. The result is an electricity market with prices closer to marginal costs.

Our conclusion, however, was qualified by the possibility that the contract market might deter entry that might otherwise occur and, hence, could lead to higher electricity prices in the long-run. This analysis of the possible dynamic consequences of contracts is only a beginning. In particular, signing a contract can make current generators less flexible to informational changes. A fruitful direction for future research, therefore, is to consider the interaction between pool and contract markets in a dynamic setting where each sends signals and provides incentives for entry and investment (as in Aghion and Bolton 1987; and Innes and Sexton 1994).

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[3] Of course, as the cost advantage grows large the range of sunk costs that might deter otherwise possible entry grows smaller.

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PANEL SESSION 2

Comments and discussion

Martin Algie (Minter Ellison)

A question for Joshua. One of your assumptions was that the generators have some degree of market power. What would be the effect if you didn't make that assumption, and I say that because I think there are good reasons for not making that assumption, if you assumed that no generator's capacity is necessary to satisfy demand?

Joshua Gans (Melbourne Business School)

In those instances we push the case towards the case in which demand is effectively very high. If demand is relatively low, as Frank talked about yesterday, if demand is low as such that there are many generators which could cover it, you could get more or less competitive outcomes. In that respect, all these strategic implications go away. But you have already got the competitive outcome anyway. Now, you will still see, in reality, contracting in that environment because of uncertainty and simple risk bearing, which is in our model. So we are speaking to the cases in which demand is particularly high and so those are the instances that von der Fehr and Harbord identified as the instances where we will be most concerned about market power issues.

Lasantha Perera (Eastern Energy Ltd)

I think what we heard from the previous speaker, John, when he was talking about what they call a loading and what Joshua is talking about in terms of contracts has very nice implications because previously we had a ...(indistinct)... loading where economics dictated the gross marginal cross units would come on line and if for an instant there was mismatch, that is a non-economic unit on line, it was inefficiency ...(indistinct)... time and you can't recover that. That's always the situation in economic efficiency that you must always have ...(indistinct)... loading to have the best economic outcome. But when you come into the pool situation the loading is not by merit order but by merit order bid price, and if the bid price is not at the marginal price, as we would expect it to be, there will be some uneconomic situations that develop which can not be rectified in time, because we had a high cost generator running for one hour even when a low cost generator could have run.

So that overall economics comes down because we have now the bid price coming in to set what should be the generator that is loaded. In that context of economic efficiency, in terms of a pool, I think the difference is that you talk about commodities like soy beans, or what ever it is, and it is slightly different because the prices set up in a sense fixed as a market price does not have an implication in terms of what is loaded, because the decision to make farm soy beans is taken very much in advance and it is not influenced by that decision at the price at which it is cleared. So we have a little bit of a mismatch, or a situation where we have a full price which is unknown and keeps going up and down, and of course to contain that uncertainty we have the contract coming in. But if you said what is the market price, is it the contract price or is it the full price? It's going to be a big question, because the item that is published which is available to most people is the full price. They don't know what the contract price is. So in a sense you can say the market is imperfect in-so-far that the market doesn't have full information to decide which is the necessary full price. I would like some comments from both gentlemen to say what do you think should be the outcome.

John Salerian (Industry Commission)

I think in the context that I was presenting, that was the optimum thing to do. If the constraint emerged then what it was saying was that at that point in time the capacity wasn't available. In the long-run it might be a signal that the system has to be changed and there might be some augmentation of transmission occurring somewhere in the system. All the point was of that was that at that point in time it, in fact, was socially optimal — it was the economic equilibrium to actually run the more expensive generator and the only reason for that was because of the externality in the network.

By doing so it enabled the consumer at various nodes to purchase more electricity from that cheap generator. He was unable to deliver the power because of this network externality. By running one of the other more expensive ones they were then able to purchase more of the cheaper power from the cheaper generator. It probably gets caught up in the market mechanism but I think it is a slightly different question to your thing.

Joshua Gans

The question of what is the price of the electricity, you have to ask who is actually trying to determine that. If you are a retailer you know the value of any contracts you have signed and you also know the pool price, so you can work out the average price for every unit of electricity in a particular period that you have had to effectively pay. If you are a potential entrant you have got a harder problem but you can observe pool prices, and the other thing is that a potential entrant will probably have in their mind trying to secure some contracts prior to building the plant.

There is nothing against that, it is just more uncertainty so it might be difficult. So, I think these things are discoverable. We do not know in a lot of economic transactions what prices things were actually exchanging at, so we have to infer. But it should not be necessarily a barrier to price signalling the existence of a contract market.

Lasantha Perera

There is a bigger problem, because I as a retailer who has said to my customer, the price which I fix to the customer is based on my contracts, in a sense, and if the pool price comes down, the customer says “Why are you charging me so much? Look the pool price is so low”, because he doesn’t get the information about what the contract prices are. That is imperfect knowledge in the market. So the brunt of the whole system’s problem is taken up by the retailer, because he has to tell the customer "Hey, buddy, but I bought at a higher price”.

Joshua Gans

That’s true. If you have bought optimally at that higher price, if you signed the strike price optimally, you should be in no different position from your competitors. So if you have contestable customers the one thing you can say is "Well, go ahead. Go get another price elsewhere if you think it’s too high.”

Lasantha Perera

The market ...(indistinct)... comes into question in the customer’s eyes which is not very good for the market, is it?

Michael Cunningham (Queensland Treasury)

The price paid under uniform tariffs by domestic consumers in remote areas of Queensland is about 40 per cent of the cost of supply. Therefore, it seems to me there would be efficiencies in the overall system if a local supplier could supply the cost less than two and a half times the cost of the present supplier. The Government is not itself going to purchase any new capacity, so are there any incentives for local supply, where it is more efficient than supplying long distance over longer commission lines?

Donald Anderson (Queensland Electricity Reform Unit)

That is an excellent question. One of the things that obviously that inter-relates with is the CSO payments and the sharing of those. One of the issues that is a really down the track issue for us is to work out mechanisms by which the government can start sharing those CSOs back in some way with potential new investors so that can be brought into their thing. We are just working on that now.

Henry Ergas (University of Auckland)

A question for John, which relates to your overhead where you have the equilibrium prices which emerged under each of the demand scenarios. I don’t know a great deal about electricity but intuitively you would think that the difference between the equilibrium prices at the nodes should on average be equal to the long-run marginal cost of transmission, of the transmission link between the nodes, taking account of extra analysis. That is, that because the cost of transmission from point A to point B will be reflected in the price difference between point A to point B, I should build capacity up to the point where long-run marginal cost of adding to that capacity is equal to the equilibrium price difference. But looking at your numbers there seem to be virtually no average price difference between the nodes and I wondered what that meant in terms of how you had modelled the supply side of the transmission network.

My question for Joshua is if entering into contracts reduces the ability to exploit market power by the generator, then if there were a reasonably small number of generators wouldn’t you expect them over a time to broadly refuse to enter into contract?

John Salerian

The way this model was set up is that it's in a sense got long-run generation but it doesn't have long-run transmission. We didn't put in there the opportunity to invest in extra transmission capacity. If we had done that then this model would have made the trade-off between the congestion costs and transmission losses. It would be a fairly complex optimisation because it has got to look at the flows over each of the blocks, as in this case it's an annual model. It has got to build a capacity. It is going to be sitting there for the whole of the period but the losses are going to be going up and down, depending upon load flows over that link in each of those time periods. So, yes, it would do that, if we had done that; we have not.

That was one extension that we actually mentioned ...(indistinct)... you can make was to start to see how that then starts to interact with generation. What you are doing with the transmission system is quite important to the long-run efficiency of the whole system, otherwise you would get a constrained optimisation. You will get generation optimising itself around a given or a regulated transmission system. What you do with the transmission system is important in optimising the whole.

That was really where we were trying to go in the long-term, and then the other issue that we wanted to look at was the revenues created by that because the only revenues you get in the long-run are the differences between the marginal energy losses, because the marginal losses are higher than average losses. So you get this trade-off between, do I invest in the capacity and get the losses down or do I restrict capacity and get the losses up? But we were also thinking, in the long term, of the Eastlink and the Westlink and the Basslink and how they matter because it will in part determine how the incentives for potential generation to come into the system.

Joshua Gans

The answer to your question is, in the context of our model, absolutely you would expect that. But there are a lot of wrinkles. First of all, you are talking about tacit collusion, so what is critically going to hinge is the ability of generators to observe each other's contractual arrangements. The advantage of having a pool as we do is you have to bid all of your amount into the pool. You can not observe which amount of that was contracted necessarily, unless you had detailed access to each other's bid information that would be a problem, but that will always be a problem.

Moreover, because of the uncertainty and because you always have risk bearing reasons to sign contracts and retailers will demand that, it is going to be hard to distinguish between the strategic element of contracting and other elements as well. That adds to the uncertainty and would add to the difficulties of generators to tacitly collude on that dimension. There might be other reasons to be concerned about that but I would say they are probably lower on the list.

Stephen Wallace (Snowy HydroTrading)

Have you actually had a look at this relationship of contracting over multiple periods? Because my suspicion is that if you depress spot prices based on your generation in one period the future contract prices will actually go down and then you put yourself in a situation where those prices are lower than if you continue to depress prices. My suspicion is that a profit maximum strategy over multiple periods is actually to ignore contracts and bid in the spot market as if you hadn’t any, and the only purpose of contracts is just to smooth the cash flows out. Would you like to comment?

Joshua Gans

There are a number of issues bound up in what you say. The ability of you to use your market power in the pool to manipulate prices you might sign for contracts is critically dependent on the sophistication of the purchase of contracts and how they read that. So you have to make assumptions about that. But I wouldn’t presume to do in this setting.

In terms of the whole thoughts about the inter-temporal aspects of contracting can be particularly relevant if you are concerned about being despatched in adjacent time periods. Those are complicated financial arrangements and I believe that there are researchers of the University of Queensland, Steven Gray is one of them, who are actually to solve that complicated financial problem. There is no answer yet on how to do that but there are probably advantages to so doing. I think that we will still see contracting. I don’t think ignoring it will be the strategy for generators.

Stephen Wallace

I wasn’t advocating ignoring it, I was advocating the trading of the generator in the spot market ignores the contracted position in the long-term.

Joshua Gans

No, can not do that. You wouldn’t do that for simply the reason — this is why it is a domino strategy — I told you before. If you ignore your contracted amounts you could end up producing into the pool when you would be better off having purchasing from the pool and vice versa.

Stephen Wallace

That s a short-run optimisation. The long-run is once you affect the future contract prices you will realise it is not optimal to take a short-run optimisation.

Joshua Gans

And then we get into a discussion of the sophistication of retailers which is a thing I can not comment on.

Paul Hyslop (Edison Mission Energy)

We have actually seen contract prices fall in the Victorian electricity market from around $40 two years ago to under $20 now because they followed the pool price down because generators have, in fact, followed the strategy that you prescribed and if in fact they had ignored their contract positions and bid into the pool on the basis of optimising their position, they would have held contract prices up and made a lot more money in the process.

You're saying the dominant strategy is to bid in marginal costs of your contract position and I also disagree with that. I don't think that is the dominant strategy for generators.

Joshua Gans

We can argue about that later probably.

PANEL SESSION 3

Environmental regulation

Don Gunasekera
Industry Commission

Robin Stewardson
BHP Pty Ltd

Tim Fisher
Australian Conservation Foundation

PANEL SESSION 3

Invited paper 7

Role of economic instruments in managing the environment

Don Gunasekera
Industry Commission

7.1 Introduction

While progress has been made in recent years to better manage the Australian environment, significant problems remain. There is widespread concern about the degradation of our land, water and biological diversity. Community concern about environmental problems has presented some challenges for policy makers. Environmental assets and natural resources are valuable in their own right, and major sectors of the economy rely on the use of these resources. The extent to which the environment should be protected depends on the relative values placed by Australians on environmental preservation compared with use of environmental assets and natural resources.

Environmental protection and economic performance are interdependent, and environment protection can make good economic sense. Furthermore, delivering environmental objectives more effectively and using resources more efficiently is good for both the economy and the environment. Attention should be paid not only to the extent to which the environment is protected, but to how such protection is provided. Failure to pay attention to both these issues may mean Australia's productivity performance is undermined and/or the environment is not adequately protected (IC 1990).

The are various policy responses for environmental protection, including regulation, suasive measures and economic instruments. In the past, governments have relied heavily on regulation. While often effective, regulation tends to be inflexible and to provide limited incentives for innovation in managing environmental problems. More recently, there has been increasing interest in economic instruments to complement other approaches because of their potential to improve the cost effectiveness of environmental protection.

7.2 Rationale for government intervention

On their own, market forces sometimes fail to realise the socially optimal use of environmental resources due to the existence of market failures. The existence of market failures is one of the main reasons for government intervention in dealing with environmental issues.

In the context of the environment, the most common form of market failure is externalities. Externalities result when economic activities have consequences for the environment that are not translated into private costs. They are generally caused by an absence of, or ill defined, property rights.

Information failures are another form of market failure. When producers and consumers are not well informed about the environmental implications of their activities or how best to minimise them, the environmental impacts of their decisions are likely to be aggravated. Moreover, private provision of such information may be less than socially optimal.

Other reasons for government intervention to deal with environmental problems include the view that in some cases the current generation may be myopic and degrade the environment today for financial gain at a cost to future generations. This provides a rationale for government intervention to preserve intergenerational equity and ensure that the current generation makes decisions based on the full costs of any environmental degradation, where this includes the costs to future generations of action taken today. Also, some consider that there are 'public good' elements to the demand for environmental attributes, such as the demand for the continued existence of certain ecosystems, biodiversity and genetic diversity.

7.3 Forms of intervention

Government intervention to offset environmental market failures can take three main forms — regulation, suasive measures and economic instruments.

Regulation

Generally prescribes a level of pollution (or abatement) and/or the means of reducing environmental damage, and the polluter is left with no choice but to comply or face a penalty (OECD 1994a). As a result, regulation is often inflexible and provides little incentive for innovation to reduce environmental degradation. Regulation can also have high costs of administration and compliance. For all these reasons, the use of regulatory instruments in isolation from other measures is unlikely, in many cases, to be the least cost method of achieving environmental objectives.

Suasive measures

Suasive measures seek to change the perceptions and priorities by internalising environmental awareness and responsibility into individual decision making. They can take the form of education, provision of information and training as well as forms of 'moral suasion' such as social pressure and negotiation (OECD 1994a). Suasive measures can complement economic and regulatory instruments and assist in their successful implementation.

Economic instruments

Economic instruments affect the relative ‘prices’ (costs and benefits) of alternative actions open to firms. They include a range of price or quantity related measures which alter the attractiveness of different options available to individuals or firms in decision making processes. Through this, economic instruments aim to provide an incentive to decision makers to integrate environmental concerns into their everyday decisions. Such instruments are often referred to as market based instruments, as they work by using market signals, such as prices, to encourage better decisions.

Compared to regulation, market based instruments allow greater flexibility in the response of decision makers to reduce environmental damage. By allowing polluters to choose the method that is best in their particular circumstances, economic instruments allow firms to achieve environmental objectives in the most cost effective manner. Economic instruments can also make the costs of environmental protection more transparent and encourage ongoing innovation in more environmentally friendly technologies.

Economic instruments may be classified in a variety of ways. Five categories are presented in table 7.1 — charges and taxes; subsidies and tax concessions; financial enforcement incentives; deposit refund systems; and property rights and market creation.

Charges and taxes

By reflecting the extent of environmental damage caused by different activities, charges and taxes can make polluters pay the costs of such damage. Where enforceable, they ensure that producers and consumers take account, at least in some part, of the costs of environmental damage in their decisions. Whilst charges and taxes are most efficiently applied at the source of damage, this may be difficult in practice. In such cases it may be preferable to tax a cost effective surrogate.

Charges and taxes can achieve environmental objectives in an economically efficient manner. Those who are able to reduce environmental damage by introducing new technologies and cleaner production processes at a lower cost than the rate of tax or charge are encouraged to do so.

Table 7.1 Main characteristics of selected economic instruments

Type and definition	*Advantages*	*Difficulties/disadvantages*	*Relevance*
Emissions and effluent charges or taxes	— low transaction costs for firms or individuals	— setting the charge at the right level — monitoring	discharges from point sources

charges based on the quantity and quality of pollutants discharged		requirement	
Product charges levies on products which are harmful to the environment when used or disposed of	— reduces the use of products that are harmful to the environment	— setting the charge at the right level — monitoring requirements	where it is not feasible to monitor pollution from individual sources
Clean up or restoration levies a levy to raise funds for environmental clean up	— levy funds are linked to environmental purposes	— determining the relevant group to levy	to fund clean up costs caused by past (but not ongoing) activities
Subsidies payment by government to those undertaking environmentally friendly activities	— encourages action to overcome environmental problems	— externalities are not internalised by polluter — may reward poor environmental performers — may pay those who would undertake action even without a subsidy	where other economic instruments do not work or are too ‘expensive’
Performance bonds financial security lodged with government against environmental damage	— minimises the risks and potential costs of polluters defaulting on liability — encourages restoration and clean up where necessary	— setting a realistic level of security	where it is necessary to minimise the risk that environmental damage will not be rectified
Legislated deposit refund systems a refundable deposit which is paid on products which can cause pollution if discarded	— reduces the volume of waste and/or the release of toxic substances into the environment	— transaction costs may be high — significance of benefits (relative to changes in costs) not always clear	most effective if applied to products which have an existing distribution system, eg household milk containers
Tradeable permits a transferable right to discharge a prescribed level of pollutants or use a certain amount of a resource	— allocation of resources to the highest valued use — reduced information needs for regulators — more certainty regarding pollution or resource use levels	— establishing an efficient market — setting overall level and initial allocation of permits — transaction costs	where environmental impact is independent of pollution source, eg for air pollution within a defined area
Environmental liability making polluters legally liable for environmental damage	— potential polluters are forced to either adopt environmentally friendly practices or pay potential damage (through higher premiums)	— choosing the level of increase in premiums, etc. that will cover liability and risk — enforcement of liability	where environmental outcomes are linked to the availability of finance, insurance, etc.

Source: Industry Commission (1993)

Where charges and taxes are too low to provide such an incentive, they mainly serve to raise revenue. In such cases, the revenues are often intended for collective treatment of the environmental problem, research on new abatement technologies or subsidising new investment by polluters in such technologies (OECD 1994a).

Whilst there are benefits associated with charges and taxes they can also have a number of drawbacks including:

- the difficulty of determining the appropriate level of charge or rate of tax;
- the need to monitor and adjust them to ensure they meet their objectives; and
- overcoming concerns that they will become merely revenue raising devices for the government (IC 1993, p.85).

Subsidies and tax concessions

Subsidies and tax concessions can provide an incentive to modify behaviour, and in many cases give polluters the flexibility to do this in the manner they choose. A subsidy is a payment by government to those who undertake certain activities the government wishes to promote. A tax concession reduces the amount of tax owed to the government by those undertaking such activities. In both cases, government revenue is reduced and there is a financial gain to firms who undertake the relevant activities. Ideally, the size of a subsidy or tax concession should not exceed the overall benefits derived from the action or activity for which the subsidy or concession is given.

However, subsidies and tax concessions can have several shortcomings. They may not satisfy the polluter pays principle. They may reward those who have been poor environmental performers prior to their introduction, or those who would have undertaken the change in their absence. Furthermore, they represent a net payment by the government, and may also distort the tax system.

Nevertheless, there may be situations where the desired behaviour is unlikely to occur without a positive financial incentive. In such cases, the use of subsidies and tax concessions may be appropriate.

Financial enforcement incentives

Financial enforcement incentives penalise non-compliance with a certain environmental standard or regulation. There are two main types of financial enforcement incentives: performance bonds and non-compliance fees.

Performance bonds are ex-ante payments made to authorities for potential environmental damage, where the amount of payment generally varies with the level of potential damage. Performance bonds provide government with a guarantee against the risk of default of conditions prescribed for environmental safeguards, and are best suited to situations where there is one source of potential environmental damage and that damage can be reasonably estimated. Finance may be provided in various ways, including provision of up front capital funding which is refunded once compliance with certain regulations has been achieved, and taking out a loan with a financing body in a manner similar to other general cases of risk insurance.

Non-compliance fees are levied ex-post on polluters when they do not comply with certain regulations. To constitute an economic instrument, such fees would need to be linked to the rates by which prescribed limits are exceeded — fixed penalties, such as fines for non-compliance, are not classed as economic instruments.

Deposit refund systems

Deposit refund systems generally encourage reuse or recycling of goods by including a surcharge in the initial price of the good which is then refunded when the product or residual is returned to a collection system. Deposit refund systems are commonly used for items such as beverage containers, automobile batteries, tyres, aluminium cans, steel products and lubricating oil. They can reduce the volume of waste to the environment and the volume of virgin resource used.

Deposit refund systems can have drawbacks. Their benefits may be achieved at a high cost compared with alternative measures due to additional handling, transport and storage costs. Such costs may put products subject to deposit refunds at a competitive disadvantage relative to substitutes.

Property rights and market creation

Environmental problems can arise where there are no clearly defined property rights as may be the case with air, water, biodiversity and natural areas. As a result, environmental resources may be overused (The Treasury 1990).

In cases where access to the resource can be controlled, it may be possible to create new property rights. Doing so can create a market for the resource — the beneficiaries gain a means of paying for the benefits they receive from the proper management of the resource and the resource owner is compensated for the costs of doing so.

Assigning property rights can potentially reduce the need for regulation or other interventions to protect environmental resources. To work effectively property rights should be well defined (divisible and exclusive), freely transferable, enforceable and secure over the long term.

7.4 Current use of economic instruments

Economic instruments are currently being used to address a range of environmental problems in Australia. In box 7.1 are listed some of the major economic instruments currently operating in Australia. The major instruments used are discussed in more detail below.

Charges and taxes

Emission and effluent charges

Emission and effluent charges are becoming a major part of packages of economic instruments used by some States to achieve environmental outcomes. South Australia has a system of fees to support the *Marine Environment Protection Act* 1990. Fees based on the toxicity of the pollutant, the sensitivity of the environment and the volume discharged are levied on all point source discharges to tidal waters. The charging system is expected to become an incentive based effluent management system rather than one designed, as it presently is, to cover administrative costs.

Load based licensing schemes

Load based licensing schemes provide an incentive for firms to reduce discharges and effluent to air (eg. sulphur oxides, nitrogen oxides), water (eg. salinity, phosphorus, oils and greases) and land (eg. waste water irrigation). A load based licensing system operates in Victoria for waste to air, water and land as well as noise emissions. Since the scheme commenced operation in 1991, fees for individual licences have been based on the volume and nature of the waste. The scheme currently covers about 1200 licences, which primarily cover operators of industrial premises (eg. pulp/paper mills, tanneries), landfills (eg. rubbish disposal) and waste treatment plants (eg. sewage, industrial and chemical treatment plants).

Western Australia has introduced a tiered licensing system with three types of licences for emissions to air, land and water — regulated, monitored and best practice licences. Licensees are allowed some choice in the type of licence, and therefore the basis of fees paid. Firms who do not accurately monitor discharges hold regulated licences and pay the highest fees based on the amount of waste licensed to be discharged. Firms who monitor discharges are able to hold monitored licences and pay lower fees based on the actual volume of discharges. Best practice licences involve an approved environmental management system, an approved continuous improvement plan and audits, and do not require payment of load based fees.

Box 7.1 Some economic instruments used in Australia

Charges and taxes

- A system of effluent charges in South Australia to support the *Marine Environment Protection Act 1990*
- Load based licensing schemes in Victoria and Western Australia covering air, water and land pollutants
- Trade Waste Program operated by the Sydney Water Corporation
- Product tax operating on ozone depleting substances

Subsidies and tax concessions

- Tax concessions for improved land and water management under sections 75B and 75D of the *Income Tax Assessment Act 1936*
- Local government rate concessions to encourage sustainable land management
- Subsidies and grants for tree planting and vegetation protection

Financial enforcement incentives

- Queensland Environmental Policy for Mining (performance bonds)

Deposit refund systems

- South Australian beverage container deposit scheme

Property rights and market creation

- Hunter River Salinity Trading Scheme
- Murray-Darling Basin Commission Salinity and Drainage Strategy
- South Creek Bubble Licence Scheme to reduce phosphorus levels in the Hawkesbury-Nepean river system

Other economic instruments

- Victorian Accredited Licensee Scheme
- Murray-Darling Basin Commission cost-sharing framework for on-ground works

By late 1997 the Environment Protection Authority (EPA) in New South Wales is expected to introduce a load based licensing scheme covering air, water and land pollutants. The fees will be calculated on a similar basis to those of the South Australian scheme described above. Industries initially to be covered by the scheme include cement works, coal and other mines, electricity generation, livestock processing and sewage treatment plants.

Charges for waste treatment and disposal

Charges for waste treatment and disposal are widely applied for household and industrial waste water but not all have demonstrably affected behaviour. There are several examples of industrial user charges for waste disposal via the sewerage system. The Trade Waste Program of the Sydney Water Corporation has cut discharges of certain pollutants since its introduction. Melbourne Water in Victoria and the Hunter Water Corporation in New South Wales have charges for waste disposal and there is some evidence that firms have modified their discharges in response.

User charges for natural areas and amenity

User charges for natural areas and amenity are applied by all levels of government for access to natural areas such as national parks, recreation areas and conservation reserves. Most fees are set at a level which allows maintenance of facilities rather than to ration resource use or maintain flora or fauna.

Product charges and taxes

Product charges and taxes have been imposed on a range of products that cause pollution. One example is the scheduled 2 cents per litre differential in excise tax between unleaded and leaded petrol to favour the former. Another example is the charges on ozone depleting substances applied as part of the Ozone Protection Strategy, however the fees have been designed only to recover administration costs.

Environmental levies

Environmental levies are used to finance environmental improvement programs and projects. In 1989 the Sydney Water Board introduced a Special Environmental Levy (SEL) of $80 per household per year to finance a range of initiatives to clean up the ocean, beaches and polluted waterways. The SEL has now been replaced by a user pays system of pricing. Levies are also imposed by some local councils. Brisbane City Council has a levy of $30 per year per household to purchase bushland remnants. Other councils with levies include Eurobodalla in New South Wales, and Caloundra, Cooloola, Logan, Johnstone, Toowoomba and Albert in Queensland.

Subsidies and tax concessions

Subsidies and tax concessions implemented in Australia to encourage actions with positive environmental outcomes include concessional taxes, tax concessions, subsidies, grants and rate concessions.

Concessional taxes

Concessional taxes are used to promote more environmentally friendly alternatives to conventional products. An example was the sales tax exemption for products made of recycled paper — it was abandoned in 1995 because it distorted the importation of recycled paper products.

Subsidies and tax concessions

A range of subsidies and tax concessions have been used by various governments to encourage landholders to address land degradation and promote sustainable land management. These include tax deductions and rebates, subsidies and grants for tree planting and protection of vegetation, and local government rate concessions.

Sections 75B of the *Income Tax Assessment Act* allows capital expenditure for conserving or conveying water to be depreciated over three years. Section 75D allows full deductibility in the year of expenditure for capital expenditure to control degradation of farmland. The Australian Bureau of Agricultural and Resource Economics (Mues, Moon and Grivas 1996) has found that these provisions were of some importance for most farmers with land care expenditures.

Cash donations to approved environmental organisations are tax deductible. Donations of land with conservation value are also eligible if the land has been owned for less than 12 months or is of national cultural heritage significance. However, these conditions may limit the effectiveness of this provision.

Grants

Commonwealth programs such as Landcare and One Billion Trees provide grants for the better management of natural resources. Grants and subsidies are also available in a number of States from a variety of sources to fund activities related to management of native vegetation.

Rate concessions

Rate concessions of various kinds are used by some local governments to encourage adoption of environmental protection measures by landholders. One example is the rate rebate by Melton Shire Council in Victoria. The rate rebate is given to non urban properties larger than two hectares for completed works to prevent land degradation.

Financial enforcement incentives

Performance bonds are being used in Queensland and New South Wales as an inducement for mining companies to rehabilitate mined areas. The size of the bond is based on the likely cost of rehabilitation. Bonds can be provided in various ways. Capital can be paid up front and held in trust, then refunded when compliance is achieved, however this may place constraints on the firm's cash flow. A loan can be taken out with a financing body to overcome this constraint, with the annual cost being interest on the loan. Payment of a risk premium to a bank, insurance company or other financial institution can also be made.

Performance bonds may also be used for other environmental protection purposes. In South Australia, bonds are a component of a fee based licensing system aimed at reducing the amount of effluent discharged into marine waters (James 1997). In New South Wales bonds may be prescribed by the EPA in Pollution Reduction Programs (PRPs) negotiated with industry (James 1997). PRPs are an agreed program of works or emission targets to improve environmental performance set to agreed time frames, and are attached as a condition to pollution control licences (NSW EPA 1996).

Deposit refund systems

Deposit refund schemes on recyclable containers were once common in Australia. Disposable containers made many such schemes redundant. However, some manufacturers do pay for recycled cans and bottles and this has resulted in improved collection services.

The only State which has legislated a deposit refund scheme is South Australia. Return rates for South Australia are 70 per cent for plastic, 82 per cent for aluminium and 83 per cent for glass containers. These rates are well above return rates from other States.

Property rights and market creation

To date, property rights and market creation mechanisms have not been used greatly in Australia but they are receiving more attention. They generally have the significant advantages of being self funded and of allowing participants to determine the extent of their financial involvement.

Tradeable permits

Tradeable permits are a particular example of creating a market for an environmental resource or a by-product by allocating private property rights. This instrument works first by establishing some multi-source limit on environmental degradation, such as a limit on total pollution/emissions of substances or the level of use of a resource. This limit is allocated amongst participants, who are then free to trade their permits between each other or with other interested parties. Firms for which the marginal cost of abatement is relatively high will buy permits from those who can reduce environmentally damaging behaviour relatively more cheaply, as long as the price of the permit is below the marginal cost of abatement for the high cost firms. Low cost firms will agree to sell their permits to high cost firms as long as the price they receive for the permits is greater than the cost to them of abatement.

The Salinity and Drainage Strategy, managed by the Murray-Darling Basin Commission, includes a salt credits trading scheme to reduce the level of salinity in the Murray-Darling river system. This scheme operates between the irrigation districts of New South Wales, Victoria and South Australia. The scheme appears to be achieving its target reductions in river salinity.

The Hunter River Salinity Trading Scheme is another example of a tradeable salt discharge scheme, operating along the Hunter River in New South Wales. This scheme involves 11 coal mines and two large power stations who amongst them are licensed to discharge a total predetermined level of saline water into the river or its tributaries. Within the total level of discharge, each firm is allocated discharge ‘credits’ which they are free to trade with other credit holders. As well as limiting pollution to a predetermined level, this scheme has given the local community confidence that new mines will not increase overall pollution levels, and thus new mine developments have since gone ahead with increased community support.

In New South Wales the South Creek Bubble Licence Scheme is a quasi-tradeable permit scheme operating to reduce phosphorus levels in the Hawkesbury-Nepean river system. The main source of phosphorus is sewage effluent from three Sydney Water sewage plants. Under this scheme, the EPA sets an aggregate load limit of phosphorus discharges for the bubble as a whole and allows Sydney Water Corporation to determine the load allocation between the plants so as to meet the overall required reductions in phosphorus levels at least cost.

Environmental liability

A market is also being created in the area of environmental liability, as financial institutions are starting to take such liability into account when assessing risks associated with the capital they lend. In Victoria, lenders who finance firms whose activities involve a high degree of pollution are subject to limited liability for cleaning up any environmental spills. As a result, companies with good environmental records are more likely to obtain finance at a lower cost than competitors with poor environmental performance.

7.5 Extending the use of economic instruments

This section summarises the contemporary use of economic instruments to address some key environmental problems and suggests opportunities to extend the use of economic instruments in addressing these problems.

Five aspects of the environment are considered, consistent with the approach taken in *Australia – State of the Environment 1996* (SEAC 1996). These are the atmosphere, inland waters, the coastal environment and the sea, land resources and biodiversity. This coverage is not meant to be exhaustive.

Atmosphere

At a global level, greenhouse gas (GHG) emissions and stratospheric ozone loss are key issues. At a local level, loss of urban air quality is of concern in some areas.

Greenhouse gas emissions

Australia’s approach to reduce greenhouse gas emissions is currently based on ‘no regrets’ abatement action. However, it is unlikely that no regrets actions will be sufficient for Australia to meet existing international abatement commitments. Other policy options to reduce GHG emissions include carbon taxes and tradeable emissions permits.

A carbon tax is a levy on the carbon content of fuels which, when burned, release carbon dioxide. Such a tax would encourage energy producers to improve energy efficiency or substitute towards less polluting fuels.

A tradeable emissions permits scheme for GHGs would mean that polluters who wish to emit these gases would need to either possess the required number of emissions permits or achieve the necessary pollution abatement. The total number of permits on issue would reflect the desired overall level of GHG emissions for a given period. Both national and global tradeable permits regimes have been suggested for controlling GHG emissions.

A tradeable emissions permits scheme has some potential advantages over a carbon tax. A permit scheme may be able to cover more sectors than a carbon tax. A permit scheme can also allow non-polluters to buy but not use permits to reduce total emissions. Furthermore, carbon tax rates would need to be revised more often — with changes in technology, incomes and public attitudes and preferences. Finally, the transparency of compliance with a tradeable permits scheme may be greater.

Stratospheric ozone loss

There has been significant action to address stratospheric ozone loss in Australia. Under the Ozone Protection Strategy, the Commonwealth Government has introduced stringent regulation to phase out the use of ozone depleting substances, and a product charge on products that use ozone depleting substances. So far, the approach appears to have been successful in phasing out the use of chlorofluorocarbons and is on target to phase out hydrochlorofluorocarbons. No further initiatives are expected to be needed.

Urban air quality

As motor vehicle usage increases in urban areas there is a greater likelihood of a loss in urban air quality from increased photochemical smog and airborne lead levels. Economic instruments could help to limit emissions growth. Differential taxes on motor vehicles, based on the rate of emission of pollutants, could be used to influence consumer preference towards vehicles that are more environmentally friendly. Road use charges could be used as a variable pricing mechanism based on how often and when the road network is used (NSW EPA 1994a). The Industry Commission recommended the progressive introduction of electronic user charges in its report on *Urban Transport* (IC 1994). The technologies required for such a system of charges are already established and in use overseas but require substantial investment in road based and in-vehicle equipment.

A tradeable emissions permit scheme may be able to be applied to vehicle suppliers to achieve specified cuts in vehicle emissions. Such a scheme would allow vehicle suppliers to reduce the weighted average of emissions rates across all vehicles they sold, and thus allow suppliers flexibility in achieving vehicle emissions reductions. At present all vehicles have to meet the same emission standard.

A ‘cash for clunkers’ scheme also has potential to reduce vehicle emissions. Such a scheme involves organisations purchasing and retiring vehicles with high emissions rates, for which they receive emissions credits. Credits can then be used to meet their own emissions reduction requirements or sold to polluting firms.

Inland Waters

Inland waters and related habitats are being adversely affected by pollutants, exploitation of water for economic uses and the clearing of native vegetation. Three of the more significant environmental problems are salinisation of waterways, nutrient enrichment and overuse of water.

Salinity of inland waterways

Salinity of inland waterways can be caused by dryland and irrigation salinity. Therefore, measures to address dryland salinity have the potential to reduce salinity of inland waters — dryland salinity is discussed later in this paper under ‘Land resources’. The main economic instrument applied to address irrigation salinity is the tradeable salt permits scheme operating in the Murray-Darling Basin. There is scope for this scheme to be expanded to include dryland areas. As irrigation practices are a major cause of salinity, measures to improve the efficiency of water use are also important, as is appropriate water pricing. Water pricing will be discussed below under ‘Increased demand for inland water’.

For point sources of saline discharges such as mines and power stations, output based measures are appropriate. Options include charges and taxes on salt output, subsidies for activities to reduce salty discharges and tradeable salt permits schemes. There is potential to extend the Hunter River Salinity Trading Scheme to other point, as well as non-point, sources of salinity.

Whilst including other point sources should be fairly straightforward, involving non-point sources in a tradeable permits scheme is likely to be more difficult. However, a potential system could see point sources obtaining extra discharge credits by investing in works that will contribute to a reduction in salinity from non-point sources. Credits earned by point sources in this way could then be used to offset requirements for load reductions from their own operations. Point sources could also be allowed to earn credits by contributing to a financial fund that implements best management practices for non-point sources which are required to improve their environmental performance. The potential for the Hunter River Salinity Trading Scheme to be expanded in these ways has been recognised by the New South Wales EPA (NSW EPA 1994b).

Nutrient enrichment of inland waters

Nutrient enrichment of inland waters is mainly caused by nitrogen and phosphorus in discharges from sewage treatment plants, as well as eroded soils, fertilisers, septic tanks and animal wastes. Nutrient enrichment can degrade the health of water environments by killing flora and fauna species and producing algal blooms. Discharges from point sources such as sewage treatment plants present an opportunity for the application of tradeable permit schemes. There is potential to extend the use of tradeable permits or offset schemes to a range of nutrient discharges and to regions and States where they currently do not exist. For example, the South Creek Bubble Licence Scheme on the Hawkesbury-Nepean river system could be extended to other point and non-point sources of phosphorus, in a similar manner to that described above for the Hunter River Salinity Trading Scheme. Where tradeable permits schemes are not cost effective, an alternative instrument for point sources of nutrient discharge is a tax or charge on nutrient levels.

Overuse of inland water

Increased demand for water is placing increasing pressure on the environment of inland waters and contributing to land degradation. Use of water for irrigation accounts for around 70 per cent of water use in Australia. Much irrigation water is used inefficiently for marginal economic benefit (SEAC 1996). Full cost pricing of water and tradeable water entitlement (TWE) schemes are two measures that would provide incentives for more efficient water use.

Water for irrigation purposes is currently subsidised by governments through the provision and maintenance of infrastructure. Therefore, water prices do not fully reflect either the direct costs of water storage and distribution or the indirect environmental costs associated with diversion of water and problems of land degradation from irrigation. Full cost pricing of water would ensure that the amount of water used for irrigation coincides with the socially optimal level of water use, and may encourage irrigators to adopt water saving technologies.

While TWE schemes currently operate in some States, there is potential to extend their use to those States where they currently do not exist. There is also potential for interstate trading in water. A trial in interstate water trade is currently operating in the horticultural Mallee border regions of New South Wales, South Australia and Victoria. The trial is testing solutions to a number of impediments to efficient interstate water trade. Once the trial has been completed, there is potential for an amended scheme to be expanded to other areas. Potential also exists for a TWE scheme to operate between different industries or sectors.

Coastal environment and the sea

On the whole, Australia's marine and estuarine environments are in good condition (SEAC 1996). However, in areas close to major urban centres or considerable human activity, the environment can be significantly affected. Some of the more significant environmental problems facing the coastal environment and the sea occur as a result of coastal development, exposure of coastal waters to contaminants, recreation, tourism and fishing.

Coastal development

There is scope for economic instruments to complement regulation to manage coastal development. Such instruments could include performance bonds, user charges, load based licensing schemes, effluent charges and environmental levies.

Performance bonds for coastal developments would operate in much the same way as in other applications of this instrument. Developers would be subject to the loss of a financial bond if they breach or failed to meet previously agreed environmental conditions.

Development of coastal subdivisions has occurred in some cases without adequate infrastructure. In addition to provision of adequate infrastructure, economic instruments such as user charges, load based licensing schemes and effluent charges have the potential to help minimise pollution and the volume of wastes to be disposed. Environmental levies could also be extended to help address the environmental impacts resulting from development.

Contamination of coastal waters

Contamination of coastal waters by nutrients, sediments, chemicals, heavy metals and litter can lead to algal blooms, habitat degradation and poisoning of marine species, and can accumulate in fish and other organisms. The main sources of contaminants include agricultural run-off, sewage effluent discharges and urban stormwater (SEAC 1996).

The measures discussed previously to address the problems of nutrient enrichment of inland waters can also reduce the flow of sewage effluent and agricultural run-off into coastal waters. Sedimentation is a similar problem and can be addressed using similar measures.

Sewage outfalls can also carry significant quantities of industrial discharges. Trade waste charges based on polluter pays principles provide incentives for industry to reduce discharges to the sewerage system, and should be applied where possible to reduce the impact of trade waste discharges on coastal (and inland) waters. As mentioned previously, load based licensing schemes and effluent charges based on the quantity and quality of pollutants also have potential to reduce pollution arising from coastal development.

Urban stormwater is now recognised as a major pollutant of the coastal environment. Economic instruments have potential to complement engineering and suasive measures to reduce the quantity of stormwater and improve its quality. Tradeable permits to discharge stormwater are one means by which local councils could regulate the quantity of stormwater discharges from new developments. Developers could trade the right to discharge stormwater so that the overall discharge from the catchment can be limited. User pays pricing principles could also be applied to the treatment of stormwater (CEPA 1993).

Impact of recreation and tourism

Recreation and tourism can place substantial pressures on the coastal environment. Large, often seasonal, influxes of tourists can have significant environmental consequences, including beach and dune erosion, trampling of reefs and vegetation, loss of habitat to facilities and declines in wildlife and fish stocks. Economic instruments with potential to complement suasive and regulatory measures to address these problems include charges and taxes, tradeable permits, deposit refund schemes and financial enforcement incentives.

Effluent charges based on the quantity and/or quality of discharges to the environment from tourism facilities such as hotels could be utilised more extensively throughout coastal areas. User charges could also be applied more extensively to reflect the full costs of provision and management of tourism facilities. Taxes on tourism related goods and services also have the potential to ensure that tourists contribute to the costs of environmental protection when applied to complementary goods and services.

Deposit refund systems could be utilised more extensively to manage waste generated from tourism. There is also potential to apply performance bonds more widely, particularly for tourism developments that pose environmental risks if development guidelines are breached.

Impact of fishing

Fishing can exert pressure on Australia’s fish stocks, in the form of excessive catches of species, alteration of food chains, changing species composition and alteration of the genetic composition of fish stocks (SEAC 1996). Tradeable resource use rights have been implemented in a number of fisheries. Most are effective but non-compliance can be a problem. For example, quotas in the South East Fishery are confined to Commonwealth waters, creating incentives for fishers to report some catches made in Commonwealth waters as being from State waters. There is scope to make the quota rights more clearly defined, secure and enforceable. Transferable quotas could be applied to other Australian fisheries where species are being over exploited.

Land resources

Australia's land resources have suffered from a number of environmental problems, mainly loss of native vegetation and soil degradation.

Vegetation clearance

Clearance of native vegetation has a number of impacts, including loss of habitat and biodiversity, and land degradation problems such as salinity and erosion. Removal of native vegetation also reduces nature's ability to absorb GHG emissions, and may have an impact on climatic patterns. Two of the main factors contributing to the degradation of Australia's native vegetation and forests are certain land use practices and urban expansion. A poor understanding of the value of native vegetation and the consequences of vegetation clearance have also contributed to the problem.

A number of economic instruments have been applied to reduce vegetation clearance and encourage revegetation. These include, for example, environmental levies administered by some local governments to raise funds for purchase of native bushland, and grants and subsidies provided through various government programs for fencing and other activities to conserve native vegetation. Conservation covenants and management agreements between government or non-government organisations and landholders have also been used to encourage native vegetation retention. These can specify terms of management, can be legally binding and can offer financial incentives, as well as providing support and information to landholders. There is scope to extend the use of management agreements and conservation covenants to protect areas of conservation value.

There may also be scope for the use of other property right instruments such as tradeable rights to cleared land, in which landholders would be able to buy or sell rights to cleared land. However, the practicality of such a scheme would need considerable further research, and attention would need to be given to issues such as trade between areas of high and low conservation value and how to assess the conservation value of different areas.

Soil degradation

The major types of soil degradation in Australia include salinity, soil erosion, soil acidification and soil structural decline. The two main causes of most forms of soil degradation both relate to changes in land use — land clearance, and certain farming and irrigation practices undertaken by landholders.

To date, most problems of soil degradation have been addressed through government funded research, development and information extension activities. There has been limited use of economic instruments to address soil degradation problems, and there is further scope to extend their use.

Where soil degradation problems are related to land clearing, instruments to address vegetation clearance and encourage revegetation discussed previously are likely to help. Where problems are related to land management practices, it is likely that these practices are a result of lack of information about their impact on land degradation. Therefore, there is a case for government to continue funding research, development and information extension activities.

There are several forms of ***salinity***, of which dryland salinity and irrigation salinity are the most common. To date, no economic instruments have been applied to directly address the problem of dryland salinity, although instruments such as grants, tax concessions and local government rate rebates to encourage vegetation retention and revegetation may have some impacts. There may be scope in the future (if adequate information and viable technologies become available) to extend to dryland areas the salt credits scheme currently operating in irrigation areas in New South Wales, Victoria and South Australia. Again, such a scheme would need considerable further research.

Irrigation salinity occurs as a result of inefficient irrigation practices which cause watertables to rise, bringing salts to the surface. In terms of economic instruments, irrigation salinity has been addressed through the implementation of the above mentioned tradeable salt credits scheme. Such a scheme appears to be the most efficient way to reduce this form of salinity. Full cost pricing of water and TWEs may help improve the efficiency of water use in irrigation areas.

Soil erosion, acidification and ***structural decline*** are often private problems where the cause and effect occur on the same land. Where this is the case, and landholders have adequate information, there is no case for government intervention. Where off-site effects exist there may be a case for government to implement economic instruments, such as taxes or subsidies, to internalise these external costs. Cost-sharing for on-ground works may also be a useful instrument in some cases.

Biodiversity

The National Strategy for the Conservation of Biological Diversity recognises that a range of measures are required to conserve Australia's biodiversity. These measures include the cooperation of a range of stakeholders including resource users and the community, improved knowledge and understanding of Australia's biological diversity, and integration of biodiversity conservation with natural resource management. The Strategy also advocates the use of economic instruments for conserving biodiversity.

Economic instruments are already being utilised to conserve biodiversity, albeit to varying degrees. This is because the conservation of biodiversity is an indirect outcome of the application of many of the economic instruments discussed in this paper. For example, water pricing reforms and the introduction of TWEs aim to encourage more efficient use of water resources, which may help to reduce the environmental pressures on inland waters. Similarly, economic instruments aimed at reducing pollution to land, air and water are likely to have beneficial consequences for biodiversity.

Significant opportunities exist to extend the use of economic instruments to conserve biodiversity. The potential to extend the use of economic instruments to encourage retention of native vegetation has been discussed previously. The potential to extend the use of economic instruments to address other environmental issues which have consequences for biodiversity are discussed elsewhere in this paper. This includes instruments to reduce pollution to land, air and water, tradeable quotas in fisheries, instruments to reduce the impacts of development and tourism in the coastal zone, and instruments to address land degradation issues and overuse of inland waters.

Biodiversity conservation could also be encouraged by the creation of markets to provide agreements for the use of genetic resources. These agreements in effect would represent payments for prospecting rights for the genetic resources of plants in a geographical area. Such arrangements could help to strengthen incentives for the conservation and sustainable use of biological resources for particular geographic areas (OECD 1994b).

7.6 Role of stakeholders

Governments, industry and the community can all play a critical role in extending the use of economic instruments to manage the environment.

Role of government

As discussed previously, government intervention in environmental problems can be justified on the basis of a number of factors including market failures. Where government action is warranted, the question of which level of government should have responsibility for a particular environmental problem is an important one. The principle of subsidiarity, which states that responsibility should reside with the lowest practical level of government, is increasingly being used to determine the most appropriate level of government responsibility in a wide range of areas (IC 1997b). Effective implementation of incentive based mechanisms to address environmental problems may also require devolving responsibility and authority to the lowest practical level.

Central governments

For environmental problems of a local or regional nature, one of the roles of central governments is to empower departments, local government organisations, non-government organisations and individuals to address environmental problems as appropriate. Central governments also have a critical role in developing effective strategies for consultation and direct participation of industry and community in the decision making process at the local level. Governments also have a role in understanding the environment and identifying environmental problems in a pro-active way, since there is no private interest in addressing these issues at an appropriate regional or national scale.

With particular reference to economic instruments, central governments have a role in resourcing research and provision of information (where this is not likely to be privately provided), monitoring and accountability, and coordinating policy including inter regional, state and national plans and strategies. For environmental problems of a national or global nature, central governments may also have a role in administering economic instruments to address those problems. An example would be the administration of a carbon tax or tradeable emission permit scheme to reduce GHG emissions. Furthermore, central governments have a role in facilitating the introduction of more efficient and effective economic instruments as improved information and technology becomes available. They also have a role in ensuring mechanisms are in place which allow instruments to be reviewed and refined as circumstances change.

Local governments

Local governments have the capacity to play an important role in addressing environmental problems of a local or regional nature, although to date this role has not been widely taken up. Local knowledge, the potential role in education and leadership, and council functions in infrastructure provision and regulation of development on private land also mean that the role of local governments is critical in addressing local or regional environmental problems.

Local governments have not played a large role in addressing environmental problems for a number of reasons. These include a lack of financial resources and the fact that local government boundaries do not usually reflect natural boundaries. A review of funding arrangements for local governments (including consideration of the possibility of making local governments more accountable for environmental performance) may be an option in some cases to overcome this barrier. Investigation of the possibility of setting up regional committees to manage natural resources within individual catchments along the lines of Catchment Management Committees may also be worthwhile.

Role of industry and community groups

Industry and community involvement in developing solutions to environmental problems is crucial. Not only do they have local knowledge which can be provided at low cost, but ownership of solutions increases industry and community commitment and the probability of compliance. Community involvement can help to overcome the credibility gap which exists when decisions are made by governments in the face of uncertainty and limited information, and can also provide valuable leverage to government funds in terms of community input of time and resources (Young et al. 1996). Through mechanisms which facilitate industry and community involvement in decision making processes, opportunities exist to learn from industry experience with respect to economic instruments, including, for example, the experience of some firms in relation to the application of economic instruments in other countries.

If a decision making role is to be given to local governments, community or industry, and taxpayer funded resources are to be used to develop solutions to environmental problems, accountability is critical to overcome any possible misuse of funds or to avoid capture by vested interest groups as well as possible conflict between private and public interests. These problems can be overcome by: devolving responsibility to regional entities; ensuring a diversity of interests are represented in decision making processes; establishing accountability mechanisms; and ensuring transparency of decision making processes. Accountability could be achieved through setting goals and performance indicators against which performance could be measured, along with regular reporting requirements and periodic independent auditing. There is also potential to use cross compliance mechanisms to force agencies to collate the appropriate data to demonstrate, in a transparent manner, that they are meeting agreed environmental objectives (Young et al. 1996).

7.7 Agenda for the extension of economic instruments

The use of economic instruments to address key environmental problems could be extended by the development of a specified plan of action which provides a platform for change and reform agreed to by all Australian governments. Such a plan could include specific issues to be considered, allocation of responsibility for specific actions and target dates for such actions. Plans for action could be developed at two levels — to progress the use of economic instruments and for specific environmental issues. Such plans should recognise that economic instruments are among a range of measures available to manage environmental problems, and that in a number of cases a mix of instruments (economic, suasive and regulatory) will be the most effective response to environmental problems.

A plan of action for governments to review opportunities to implement economic instruments or modify existing economic instruments could include the development of a ‘step by step’ guide to designing and implementing economic instruments, and a process to inform government, industry and the community of the role economic instruments can play in managing environmental problems.

The Council of Australian Governments water reform process is a good example of inter-governmental cooperation to address an environmental issue of national importance.

Areas for further work

For economic instruments to operate efficiently, supporting information needs to be available. Information needs to be comparable and consistent. Currently there is considerable scope for improving the availability of relevant information needed to design and implement effective economic instruments to address a range of environmental problems. In some cases, private investment in obtaining information may be below the socially desirable level because it is difficult for individuals to exclude others from the benefits of their own research and to cover the costs of such investment. In such situations, governments have a role in resourcing research and provision of information. Industry and community can also play a valuable role in the provision of information.

Other issues worthy of further research and analysis include:

- in relation to key environmental problems, development of performance indicators against which progress on meeting environmental objectives using various tools (including economic instruments) can be measured; and
- examination of the use of economic instruments to address particular environmental problems — examples include the possibility of designing and implementing tradeable permit schemes for land clearance and GHG emissions.

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PANEL SESSION 3

Invited paper 8

A business perspective of environmental regulation

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8.1 Introduction

My task is to discuss some of the key issues and challenges for business related to environmental regulation. This is an area of growing complexity, and one which affects most of BHP's business activities.

My focus is both domestic and international given that, although BHP has nearly 60 per cent of its assets in Australia, it is located in 70 countries around the world. Environmental regulation also is being developed increasingly through agreements that are international, but which have mounting implications for Australia's long term investment and growth.

8.2 Key issues for business

At the outset, I note two points. First, that business recognises the need for sensible and effective environmental regulation. The main issue for business is the way in which environmental regulations are developed and implemented. Of course, we are also concerned with whether or not they are consistent with investment and growth objectives, but we recognise that there sometimes have to be trade-offs between conflicting objectives, both of which may be worthwhile. In those cases what we are concerned to see is that the trade-offs are determined on facts and with full consideration of the costs and benefits.

Secondly, business needs to understand how environmental performance can be a source of competitive advantage. This involves decisions about how to go *beyond* regulatory compliance, and understanding the competitive benefits of doing so.

I want to develop these two key issues regarding environmental regulation by addressing the following two questions:

1. Is the regulatory framework in existence at present and in prospect conducive to both improved environmental outcomes *and* economic growth, and if it is not, what is the least cost approach?

2. Are there advantages for business in achieving higher performance standards than actually required by regulation?

I will try to explore these issues in a little in the time available to me.

8.3 The preferred approach

Regarding the first question, in many cases environmental regulation can be compatible with higher economic growth. However, this outcome requires regulations that are soundly based and focussed on clear outcomes, rather than technologies, so as to allow companies the maximum freedom to innovate to achieve the best environmental and commercial outcomes.

In particular, regulation should:

- have clear objectives, be based on sound science and risk management principles, and take full account of costs and benefits;
- be performance based so as to provide maximum flexibility to achieve the aims of that regulation in the most cost effective manner; and
- provide for industry consultation before any new measures are introduced.

Where such a framework is in place, acceptable growth and environmental outcomes are far more likely. Alternatively, where there is a major trade-off the costs can be kept to a minimum.

On the domestic front, we are headed in the right direction. For example, the National Environment Protection Council (NEPC) is working to improve consistency of environmental standards across Australia. This should simplify regulatory procedures, particularly for companies operating in more than one state.

We have also begun to see better coordination at the state and federal levels. The Eastern Gas Pipeline Project (EGPP) is a good example, as it crosses two states. The project required environmental assessment in both New South Wales and Victoria, and under the Commonwealth's foreign investment law. A Joint Government Taskforce was therefore established, and this greatly improved the process. We expect this to be increasingly the norm as the Federal Government and State Governments clarify their roles and responsibilities for environmental assessment.

More generally, the Government's Legislative Instruments Bill sets out a framework for Commonwealth regulatory review. This incorporates a cost benefit approach which in principle is desirable, and we hope that it will work out well in practice.

8.4 International environmental agreements

The challenge business now faces is to ensure that the same degree of rigour is applied to the increasing number of international environment agreements that will impact on both domestic and international operations.

The potential costs of ill-considered or poorly specified international agreements for Australia may be highlighted by the global warming debate. The possible implications of human-induced climate change clearly require that the world community, of which business is a part, takes prudent measures to address this issue. Any measures, however, need to pass the tests of rigour, equity and effectiveness.

Modelling by the Australian Bureau of Agriculture and Resource Economics (ABARE) indicates that uniform emission reduction targets (below 1990 levels) would impose much higher costs on Australia than most other Organisation for Economic Cooperation and Development (OECD) countries. The costs are higher because of our heavy reliance on fossil fuels, relatively high economic and population growth rates, and limited fuel substitution possibilities.

ABARE estimates, for example, that Australia’s coal output would fall by around 24 per cent relative to business as usual, while production of non-ferrous metals would fall by 60 per cent and iron and steel by over 30 per cent.[1]

A large structural adjustment would also be required. This would have serious impacts across the economy, and especially at a regional level. Welfare losses for an average Australian are estimated at over 22 times that experienced by an average European, and just under six times that for an average American.

In such circumstances, it would be bad policy for government to be party to such an agreement that imposes the burden of international adjustment so inequitably. That is the reason the Australian Government is suggesting that there should be an equitable sharing of the burden by having differentiated reduction targets (as the European Union itself does internally). One reason is that a more equitable approach would increase the chances of real progress being made.

However, differentiation would also make good environmental sense. For example, Australia is a major supplier of energy and energy-intensive commodities internationally, and these industries are highly efficient. Examples

1 See ABARE, *The Economic Impact of International Climate Change Policy*, June 1997. The findings relate to a scenario involving reductions in carbon dioxide emissions from fossil fuel combustion to 1990 levels by 2010 and to 10 per cent below 1990 levels by 2020.

include production of clean coal and LNG. Locating these activities in Australia can therefore *reduce* net global greenhouse emissions.

Another major problem with the present proposal is that whatever it does, it will have little overall effect on global emissions. That's because it excludes the non-Annex 1 countries (that is, basically the non-OECD countries), and yet most of the growth in emissions to 2020 is expected to occur in these developing countries.

So what is the appropriate policy for reducing greenhouse gas emissions? Clearly it should involve differentiated targets, on both economic and environmental grounds, and it should involve everyone.

In addition, voluntary initiatives such as the Greenhouse Challenge are important. As an example, BHP's use of coal seam methane to generate electricity is having considerable environmental benefit. Not only does it prevent methane being released into the atmosphere, it also reduces emissions of carbon dioxide from electricity production elsewhere.

I would add that such initiatives will only work where they have widespread community acceptance. This involves recognising local communities as relevant stakeholders, and including them in the process of achieving better environmental outcomes.

8.5 Environmental regulation and trade

Another area of environmental regulation requiring greater rigour and scrutiny relates to market access and trade.

The distinction between environmental regulation and market access is becoming blurred as trade restrictions, product handling, eco-labelling and other requirements become part of the regulatory landscape.

There are two aspects to this issue.

First, international agreements may be used simply as a disguised form of industry protection or promotion. Such actions raise serious concerns from the perspective of national sovereignty, given that many countries are simply unable to afford the levels of environmental amenity that we enjoy and may have different priorities. There is also a danger that environmental regulation could, in reality, be used to protect industry in developed economies.

Secondly, there is an increasing tendency to use trade restrictions to enforce environment agreements. As at February 1997, for example, there were 18 multi-lateral environment agreements (MEAs) containing trade provisions, and at least some of those raise serious issues in relation to World Trade Organisation rules.

The Basel Convention on Transboundary Movement of Hazardous Wastes is an example. Parties to the convention will meet in October to consider a ban on trade of hazardous wastes, including those destined for recycling, from OECD to non-OECD countries. I note that the Australian Government ratified the convention before its implications were fully understood, and with limited consultation. Hopefully, the Commonwealth's new treaties ratification process will avoid this in future, but there are no guarantees.

The problem with trade restrictions is that they can be extremely costly, and may do little to improve environmental outcomes.

The Minerals Council of Australia is developing a set of principles on trade and environment to address these concerns. The principles seek to strictly limit the use of trade measures. In my view, there is no perfect solution to this problem, but the position adopted by the Minerals Council establishes a reasonable basis for policy development.

In summary, international agreements can be extremely costly for Australia through their impact on trade and investment. In some cases, the regulatory mechanisms are also unlikely to be effective. The Government therefore needs to consider carefully the extent of these costs, and ensure that the burden is shared in an equitable manner.

8.6 Is compliance sufficient?

I would like to turn now to the second question I posed at the start, namely, is compliance sufficient, or should industry aim to achieve performance standards beyond those required by regulation?

My view is that where regulations are not well developed, or do not adequately protect the environment, then we *should* seek to do better. While a higher level of performance will, in most cases, involve increased direct costs, in reality it can also make good commercial sense.

There is a number of reasons for this. One is that a strong environmental record can improve a company's reputation, and this can increase its acceptability to host governments and communities.

Community expectations are particularly important in the resources sector, and may go beyond strict regulatory requirements. It is now standard practice for BHP to consult widely on environmental issues, and community concerns are often taken into account in a project's design.

Another possible reason is that better environmental performance can improve a company's share price. This could happen where a company is recognised as being able to manage complex environmental issues in an effective way. However, I think that further work is needed here before any conclusions can be drawn.

A further suggestion is that environmental regulation may bring its own benefits to companies through driving resource efficiencies. This point has been made by Michael Porter of Harvard University.[2] His analysis is supported by evidence of selected firms (including Dow Chemicals, 3M, Du Pont) and industries (the Dutch flower industry, Scandinavian pulp and paper). It implies that improved environmental performance can be achieved largely in a 'win-win' manner.

However, this analysis draws on selective examples and its conclusions should not be applied universally. Not all firms will be in a position to benefit in the manner described. Environmental innovations may also become increasingly expensive over time where regulations are progressively tightened. It is also unclear why regulation should be required to stimulate commercial innovation which is normally stimulated by competitive cost and market pressures.

So there are some good reasons pushing companies to go beyond compliance levels imposed by regulation, though the Porter point is not as commercially applicable as is sometimes claimed.

8.7 Conclusion

To sum up, I've discussed two main areas. First, environmental regulation can involve significant trade-offs between business and environmental objectives — but it need not. Trade liberalisation, growth and environmental objectives can often be mutually reinforcing so long as policies are carefully considered against appropriate criteria. Where there are trade-offs to be made, the regulations should be based on fact and assessment of the costs and benefits. Formal regulatory processes also do not hold all the answers, and voluntary undertakings can be a valid alternative in many cases.

Secondly, there may also be good reasons for firms to go beyond minimum regulatory requirements. The main advantage is that firms can improve their business prospects, through their reputation at the government and community level.

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[2] See Porter M., 'Green and Competitive: Ending the Stalemate', *Harvard Business Review*, 1995.

PANEL SESSION 3

Invited paper 9

Deregulation, competition policy and environmental performance: a case of throwing the baby out with the bathwater?

Tim Fisher
Australian Conservation Foundation

9.1 Introduction

Westernport Bay is one of any number of practical examples of how an evidently benign action — the use of groundwater for irrigated horticulture — can have unexpected environmental and economic consequences. In this case, groundwater extraction in the 1970s and 1980s depleted the aquifer to the extent that positive pressure from seawater created a saline intrusion problem, requiring a moratorium on water use for a period. That same period — particularly the mid-1980s — saw a major decline in the seagrass beds of Westernport; coastal mudflats listed under the Ramsar Convention for wetlands of international significance. Not only has this affected fish stocks in Westernport, but it also means that the penguins at Phillip Island (a major tourist drawcard) now have to swim a lot further to get a feed.

In this case, early intervention by the Victorian Government to require aquifer modelling, environmental impact assessment and regulation of groundwater extraction could have saved a lot of time, money, seagrass, fish and penguins.

In this paper I want to argue three main points.

1. Environmental and resource degradation invariably involves significant economic externalities and market distortions — *it's just that we are not very honest or systematic about investigating them*.
2. Given these externalities, efficient and accountable regulatory and policy intervention by Government is warranted — *a case for review is also presented.*
3. Environmental objectives are *not inconsistent* with competition reforms and the principles of competitive neutrality.

9.2 Economic dimensions of environmental degradation

The following are two broad categories of environmental degradation where I have attempted to summarise their major economic downsides.

Similar examples can be found everywhere.

River regulation and water extraction

Environmental Impacts:	*Economic Impacts:*
• seasonal variability is reversed, disrupting natural ecological cycles • floodplains, wetlands and billabongs dry out	• the value of commercial and recreational fisheries declines. Note that coastal fisheries yields are closely related to river flows
• river estuaries suffer from reduced river flows and changed water chemistry	• recovery plans required for those species hardest hit by changes (fish, waterbirds, etc)
• deep, cold water releases kill aquatic fauna • in-stream structures block fish migration	• remedial works required (fish ladders; erosion works, revegetation, etc.)
• in-stream flows increase relative to over-bank flows, causing erosion, bank instability and loss of habitat	• some wetland and floodplain-dependent industries decline (redgum logging; birdwatching; tourism)
• regulated sections of rivers become havens for introduced fish species	• infrastructure costs (dams, debt; etc.) mainly borne by the taxpayer
• groundwater-dependent ecosystems (some mangroves, wetlands and seagrass beds) decline or disappear	• lost fishing productivity from loss of mangroves and seagrass beds (1 hectare of mangroves worth $8 000 per annum)
	• Taxpayer-funded research and development expenditure on riverine and coastal degradation

Vegetation Clearance

Environmental Impacts:	*Economic Impacts:*
• extensive habitat destruction across vast areas	• management plans required for species and ecosystems most affected
• fragmentation of remaining habitat	• reduced farm productivity (soil degradation, salinity and soil erosion) and loss of productive land
• increased soil and watercourse erosion, soil structural decline, and loss of soil micro-organisms • increased groundwater recharge, rising water table and (often) salinity	• river and coastal pollution, reduced fish productivity, river/estuary dredging costs, tourism impacts (for example Great Barrier Reef)
• increased rate of surface run-off, heightened flood peaks, increased river sediment and pollutant loads, and siltation	• increasing rural industry reliance on taxpayer-funded productivity (and other) programs (for example, Landcare, diesel rebate, drought relief)
	• research and development expenditure on soils, water and farm productivity

9.3 Reforming oversight and intervention by governments

For many environmentalists, bitter experience has led many to interpret the word *deregulation* as getting rid of regulation irrespective of whether it is good, bad or indifferent. From a business perspective, a quick and dirty pruning exercise over any form of regulation may always seem an attractive proposition, particularly if it helps the bottom line.

A business environment free of environmental regulation may increase profits, but environmental externalities, and the economic dimensions which are invariably associated with them, means that simply doing away with environmental regulation comes at someone else’s expense, either now or into the future. Market imperfections are a fact of life, and we have to deal with them.

So the issue is not so much deregulation, but regulatory and procedural reform — how to achieve appropriate forms of regulation, oversight and intervention which achieve the desired outcome(s) effectively, consistently, and at least cost.

The need for integration in environmental legislation and regulation

A very important issue in the current complexity of environmental, natural resource management and planning legislation and regulation is that there is simply too much of it.

In a 1994 review of the *New Zealand Resource Management Act*, we compared the number of Acts in Australia with those in New Zealand, and the results were startling to say the least.

Type of Legislation	*Aust*	*NZ*	*Type of Legislation*	*Aust*	*NZ*
Air pollution	58	5	Environmental planning	144	19
Noise pollution	48	4	Fresh water pollution	138	4
Solid waste disposal	78	2	Marine pollution	86	4
Toxic/hazardous substances	120	16	Nature conservation	290	27
Resource allocation	168	8	Development	185	37

While some of this discrepancy is due to Australia’s federal system of government, this is no excuse. Basically, our resource management, planning and environmental law has evolved in a piecemeal, ad hoc and reactive fashion.

These overlapping, inefficient and sometimes conflicting and archaic laws result in confusion, delays, inertia and poor environmental outcomes.

In the late 1980s, New Zealand embarked on a review of its environmental and related legislation which was both brave and ambitious. They identified a number of problems with existing legislation including:

- high costs of working with existing laws to both industry and government;
- unreasonable delays in gaining development consent;
- existing laws often had conflicting or inconsistent objectives; and
- new and emerging issues (for example, climate change, organisms in ballast water) were inadequately covered in existing legislation.

The end result can be summarised as follows:

- replacement of dozens of separate Acts with one *Resource Management Act* 1990, covering land-use planning, water resources, coastal management, environmental protection and other issues;
- restructuring of local government to align with catchment boundaries;
- establishment of a national policy framework, a policy hierarchy and a process for developing and reviewing national and regional policy;
- delegation of the responsibility for developing resource management plans to regional government; and
- a single development consent process for any development proposal covered under the Act.

Despite lots of interest in adapting this approach to Australia's federal system, no Australian government has made any moves towards a New Zealand-style review of its legislation. Cross-portfolio reviews of any kind are taboo, it seems, and no one in Government seems willing to move into this volatile territory. But we believe that the time for reform is well overdue.

Confusing *Method* with *Aims and Objectives* — a common problem

One of the most common malaises in environmental regulation is the tendency to confuse the *method* to be used in managing a particular environmental impact with the actual *aims and objectives* that you want to achieve. This is a subtle but critical distinction if any reviews of environmental legislation and regulation are to be effective.

From an environmental perspective, the legislation and regulations for the Sydney Water Corporation is the most progressive for any water agency in the country. But it is not without its faults. One of these is the legislated requirement that Sydney Water work towards an ultimate end to all dry-weather discharges of sewage effluent into receiving coastal and river waters, thereby requiring 100 per cent water recycling.

On the positive side, this requirement has been one of the driving factors behind a comprehensive review of wastewater management and related issues.

But the legislated objective is actually only one of several methods of dealing with the problems of wastewater quality on the one hand, and growth in demand for potable water on the other. What is more, it is almost certainly not the best or most cost effective method of doing so — achieving 100 per cent water recycling from sewage effluent would be massively expensive, and would probably have a variety of undesirable impacts on the environment.

However, if Sydney Water's objectives in this instance were re-described in terms of:

- sewage effluent disposal standards appropriate for the receiving waters in question; and
- aims and parameters for water conservation, water consumption and wastewater recycling

then good environmental objectives can be realised much more efficiently. A consultative process looking at these issues is currently underway.

Sewage treatment standards across the country are rising, and rightly so, particularly where effluent is discharged into rivers or confined coastal waters.

In this context, imagine a planning authority approving town of 50 000 people where human waste was simply discharged into a large and primitive septic tank. This is precisely the regulatory environment you face in most parts of Australia if you want to build a piggery for around 10 000 pigs or so (equivalent to about 50 000 people).

If the objective is to protect human health and water quality, there is no reason why such lax regulatory standards should apply for one industry while similarly lax standards could never be contemplated in another. But the objective in the case of the piggery effluent regulations seems to be more of a method — a way of attracting investment in piggeries.

Resource access (or 'property') rights is another area where method is often confused with objectives. I refer particularly here to the issue of permanent (or near-permanent) property rights to access a resource.

Entitlements in forestry, fishing and water resources are useful examples, where the method of allocating scarce resources — invariably *permanent* and tradeable entitlements — has been confused with the objective of sustainable management of the resource in question.

The typical approach to the issue of property rights is as follows:

1. Make an assumption that resource stocks are known.
2. Make an assumption that environmental impacts are not an issue.
3. Make an assumption that you will never have to re-visit the extent of allocation, *ever*.
4. Issue generous, permanent entitlements, either free, or at a rock bottom price.

Based on past experience, over-allocation is almost synonymous with natural resource management in Australia. In native forests, problems include inadequate data on timber resources and growth rates; fire, insect and pathogen damage; and the subsequent identification of high conservation values. With water resources, climatic variation; poor data; and lack of consideration for environmental and downstream uses are the major issues. Fisheries face similar problems, with the added complication that the relationships between populations of different species and communities (for example, shark, octopus and crayfish interrelations) is never considered.

Permanent entitlements to any natural resource are a bad idea, and there are several reasons for this:

- natural systems are naturally variable, and knowledge of our impacts on them is, at best, uncertain;
- over-allocations require expensive buy-backs (for example, abalone licences in Bass Strait) and/or politically volatile fixes (for example, over-allocation of water in inland NSW);
- the flexibility demanded in adaptive natural resource management demands a *limited tenure* approach to resource entitlements; and
- tenures of 5–15 years are perfectly adequate for most investment pay-off scenarios.

Transparency and accountability

The words *transparency* and *accountability* are used a lot these days, but to little effect I fear. At the Australian Conservation Foundation we constantly encounter examples of ad hoc-ery in decision-making, most of which display some common characteristics:

- blatant political pork-barrelling;
- a shroud of secrecy over the reasons and motives behind the decision; and

- poor environmental outcomes.

Water resource management in Queensland provides numerous examples of the lack of transparency and accountability in Government. Queensland's Minister for Natural Resources is pretending to operate under a number of key policy commitments as follows:

- the Murray Darling 'cap' — an agreement to halt water consumption at 1994 levels in recognition of the rapidly deteriorating health of the Murray Darling river system; and
- the COAG Water Resources Policy, requiring:
  — full cost recovery;
  — an end to Government subsidies in water resources infrastructure; and
  — the allocation of water specifically for environmental purposes.

The reality in Queensland is rather different:

- increasing water extraction in the border rivers region of Queensland, in open defiance of the cap agreed to by all four Murray Darling states;
- announcement by the Minister of new water storages in several locations, pre-empting the outcome of legislated, consultative processes examining environmental and water resource issues in these rivers; and
- announcement by the Minister of a $1 billion Water Infrastructure Fund aimed principally at subsidising irrigation infrastructure for cotton and sugar interests.

Planning law is another area famous for Ministerial intervention. Victoria's Planning Minister recently intervened to ensure that a proposed gambling and entertainment complex is constructed at an environmentally sensitive part of the Yarra River floodplain. If the development proceeds, it will dramatically increase the risk of flooding to properties over a large part of the Yarra valley – a risk the Government is under no obligation to cover. So why the intervention?

My point here is not that Ministerial intervention in certain processes is not warranted sometimes, just that it should be fully debated beforehand, and the reasons made explicit.

Greater transparency and accountability is required across a range areas. These include:

- reviews of existing legislation and regulation;
- planning, environmental and resource management regulation;
- regulation of utilities;
- regulation of prices charged by government agencies;

- trade practices and competition law; and
- the nature, allocation and tradeability of resource access ('property') rights.

Competitive neutrality in environmental and resource management

In the primary production sphere in particular, anti-competitive behaviour by governments and government agencies is rife. This is one area of competition policy which the Australian Conservation Foundation is very keen to see addressed.

In the debate over microeconomic reform over the last decade, agriculture and resources sectors — and more specifically, the arms of Government which service them — have not been subjected to the same level of scrutiny that other sectors of the Australian economy have. Government agencies in these areas are ripe for reform in a number of areas:

- the need for adequate accounting of recurrent and capital expenditure in servicing agriculture and resource industries;
- the need for full cost recovery to be built in to pricing structures;
- no provision for subsidies (particularly capital subsidies, for example dams; drought relief; diesel rebates) without adequate justification; and
- the need for a positive rate of return on assets.

In the water resources sector, some reforms are underway, but progress has been slow. In other sectors — forestry, for example — progress has been almost non-existent, but is urgently needed. For example, if a farmer wants to grow trees commercially, particularly hardwood, that farmer must cover all costs, cover interest foregone over the investment period (say, 20 years) and sell at a price which provides a commercial return. But how can this farmer compete against a state forestry agency selling timber from native forests at a hefty loss, in the absence of any capital accounting whatsoever, and without any requirement to make a profit?

Similar examples of uncompetitive behaviour can be found in government fisheries, minerals, energy, agriculture and water portfolios.

If anyone has seen the recent Audit of Commonwealth Natural Resource and Agriculture Programs, you will notice criticism of Landcare, where the performance of hundreds of millions of dollars in Government 'environmental' funds has never been monitored or measured to any useful extent. We are also concerned about the lack of demonstrable public benefit from these public funding programs. For example, who benefits from pasture improvement subsidies granted to the wool and beef sectors? While these subsidies are aimed at salinity mitigation, considerable doubt exists as to whether they contribute anything useful in this regard. But pasture subsidies do add considerable value to grazing enterprises, which is perhaps the real reason for their existence.

9.4 Summary

To summarise, we see competition reforms as both an opportunity and a threat for the environment. For all the reasons discussed here and more, we see a great many positive environmental outcomes being possible under competition reforms. But we nevertheless hold a number of concerns about the direction of competition reforms, driven as they are by people who generally know very little about environmental issues, and probably care even less. It is all too easy for a treasury official or economists to complain about 'green tape' without really understanding the issues involved.

I come back to my three major points.

1. Environmental and resource degradation invariably involves significant economic externalities and market distortions.
2. Given these externalities, efficient and accountable regulatory and policy intervention by Government is warranted.
3. Environmental objectives are *not inconsistent* with competition reforms and the principles of competitive neutrality.

The challenge for environmentalists such as myself is to inform and educate economists and the business community that there are mutually beneficial ways through this debate, and hopefully to start working more cooperatively towards this end.

PANEL SESSION 3

Comments and discussion

Mark Harrington (Electricity Trust of South Australia)

Don, have you considered the applicability of United States–style contingent valuation to Australia?

Don Gunasekera (Industry Commission)

In terms of contingent valuation ... we haven't looked at that particular issue. It all depends on what circumstances or for what purposes we use the particular approach.

Graciela Chichilnisky (Columbia University)

What type of evaluation do you use in the case of damages?

Don Gunasekera

We didn't look at specific evaluation methods. What we did was to give some examples, such as load base licensing and performance bonds, basically looking at areas where they have been applied but not to evaluate them. That wasn't the purpose of our exercise.

Robin Stewardson (BHP Pty Ltd)

Could I just add a comment about contingent valuation. It seems to me that it is most useful and effective the more localised the issue because people will understand the issue better and because they will realise in being asked how much they would be prepared to pay for something that there is a genuine possibility they might well be asked to pay for it. The wider and more geographically dispersed the issue, the harder it is for that particular method to be effective.

Graciela Chichilnisky

Absolutely. This has been a general finding. The most difficult thing that people have in mind with trying to decide on this valuation you have to ...(indistinct)... the problem. There is just a contest.

Dick Damania (Flinders University)

My question is more towards Don. Given the paradigm endorsed by the Industry Commission I am surprised you didn't mention anything about the double dividend gains in switching to a set of pollution based taxes or externality correcting taxes. The notion that we have ...(indistinct)... switch from the existing distortionary tax base to an externality correcting tax base and that generates a double dividend in terms of economic welfare, efficiency and so on, which is one of the key features which ...(indistinct)... the debate in the European Union ...(indistinct)... look at it and perhaps you could suggest why.

Don Gunasekera

There is some literature on that. We didn't look at that issue but if you look at Clive Hamilton's work a few years ago looking at the Greenhouse issue where he was talking about the use of carbon taxes, it could basically be just an environmental problem; it could also raise revenue. There are arguments for and against some of those concepts. But the key issue is that the tax reform is a much wider issue. The Commission is not looking at individual tax issues. That wasn't the purpose of our report. Also, in our report we did not recommend any particular measure.

The idea basically was to look at the extent to which economic instruments had been used in different areas and what lessons can we learn from that. That was the idea, rather than evaluating each and every economic instrument. This morning you talked about the double dividend taxation arrangement. You also spoke about the advantages as well as the disadvantages and also you talked about moving away from taxation to, let's say, tradeable permit schemes. It all depends on what particular sort of environmental problem that you are looking at. If you look at the Greenhouse issue, there is evidence to suggest that a tradeable permit scheme would be preferable to a carbon tax system given the uncertainty regarding the whole question of Greenhouse. So I think it is a case by case type analysis rather than just advocating one measure.

Peter Dixon (Monash University)

My remarks are directed to Robin Stewardson. Robin quoted ABARE [Australian Bureau of Agriculture and Resource Economics] results extensively in his talk. Is he worried about the fact that the ABARE research on Greenhouse is financed largely by people who benefit from burning fossil fuels? Is he worried about the fact that the model is not available for public scrutiny — it is not available to people like me to check it out or run it? Is he worried about the Prime Minister's rather exaggerated use of recent ABARE results? The Prime Minister quoted an ABARE result along the lines that Australia reducing its greenhouse emissions 10 per cent below the 1990 level by the year 2010 would reduce Australian wages by 20 per cent, which is really nonsense.

Graciela Chichilnisky

So you are asking about the use of ABARE?

Peter Dixon

Yes, I am asking about whether I might get a comment from Robin because his firm actually does help finance this model, and it seems to me it's totally inappropriate that Australia's major economic research on Greenhouse should be financed by people and firms who appear to be benefiting from continuing to burn fossil fuels.

Robin Stewardson

The short answer to your question is, no, I hope it will be and I can't be held responsible for every detail of what the Prime Minister says. To elaborate on that, some years ago, in fact generations ago, there was a Melbourne University revue which had an item which was a bit of a skit on one of Melbourne's very prominent families and in order to try and take some of the bite out of the skit the said husband and wife in the prominent family came and sat prominently in the audience every night of the performance in order to try and deter the performers. I felt rather like that seeing you up there today. No, I don't think that it's inappropriate that we are contributing to the funding of GIGABARE.

It would be very nice if the government or ABARE itself, through government funding, were able to fund it itself without us having to help them. But as I said in my speech, I think it is very important that this issue, which is an important one for Australia, should be determined on the facts and that they should be analysed and known as well as possible. So I think it is desirable that ABARE and other organisations, such as your own, do as much analysis as possible so the facts are known as well as possible. If the Government is not able to fund it adequately then I see absolutely no reason to excuse firms that have an interest in it funding it as well.

We would welcome any funding. As far as the fact that you can not run it at the moment, the GIGABARE team are working very hard to get the thing documented, to get it out into the market place to be tested by their peers, such as yourself. The problem is limited resources to actually get everything done all at once. But they are working very hard to do that, which is something that I know that you, in previous debates with other institutions, have always wanted to have done.

Graciela Chichilnisky

I have had an opportunity myself, I am taking the advantage as the chairperson here, to hear the very presentation that Peter Dixon was referring to and I was surprised to the extent that the results that were reported were relatively poorly documented. In particular, there was very dramatic results of the shift of industry away from Australia that were driving most of the conclusions. An example for Korea was also of that nature. When trying to investigate where did that come from and whether it was connected to any empirical testing or such type of situations, none have been done. I mention that because in the United States it has been shown that environmental regulation had practically no impact on the relocation of firms and this initially was believed had a big impact.

It was assumed it would have a big impact in connection with the discussion about NAFTA [North American Free Trade Agreement]. Two years later, after all the research came in, it was seen that this was theoretically possible but empirically it just didn’t happen. Here the ABARE model builds it’s assumptions on the opposite empirical conclusion. There is a number of other things of that nature. That model has no empirical basis, it is mostly a scenario running for the future and it has no clear assumptions of about what ...(indistinct)... even for that. So I also found, like Peter, that the model was in the process of perhaps being perfected. What I questioned in that situation is whether it should be put out before it is perfected and before the information is given to their peers so that we can look at it. That is my only concern because we know that business, as well as the government, sector is not as trained as the academic sector to look at models of this nature in a critical fashion. So I found the presentation nice, very interesting, very entertaining, but I worried about it, as a foreigner.

Robin Stewardson

Could I just add very quickly that there have been quite a lot of presentations of not just the model output but the model itself to a group, and Peter could probably help me with the name of it, I think it has either met in Japan most recently or maybe it is based in Japan, of model builders who review and critique models for one another.

Peter Dixon

If I may, I think the only definitive way of having a model reviewed by peers is to make it available and let people who are not particularly friendly to it to actually run it. That has been the approach of the IAESR [Institute for Applied Economic and Social Research], when I was there, and the Centre of Policy Studies, when I was at the Centre of Policy Studies and the Impact Project for many years. We made our models available to people who were not particularly friendly to us and that is the way that you find out what you have got wrong with it. I can encourage ABARE to do to the same.

Robin Stewardson

They are trained to do that as quickly as possible.

Peter Dixon

I think it may well be premature for the Prime Minister to ...(indistinct)... the policy on ABARE simulation before that process has happened.

Graciela Chichilnisky

I will have to suggest that we move to another debate, but I thank very much Peter Dixon for this information and the discussion has been very enlightening.

PLENARY SESSION 1

Invited paper 10

Procuring universal telephone service

Paul Milgrom
Stanford University

10.1 Introduction

One of the hallmarks of modern society is its pervasive reliance on telecommunications. Progress in telecommunications has deeply changed the nature of social relations, politics and commerce. Individuals and communities with limited access to modern communications are disadvantaged in their efforts to keep abreast of current news, to participate in public debates, and to make their opinions known to the rest of the world. Business firms need electronic communications to integrate their far-flung operations. Much more than in the past, firms can now depend on distant suppliers to be well enough informed to react quickly to their changing needs. Combining rapid communications with flexible manufacturing technologies enables firms to make customised products that respond to individual customers' changing demands (Milgrom and Roberts 1987).

When a geographic area is cut off from modern communications, that creates a tear in the social fabric, separating the residents from the rest of society. That is perhaps the most compelling reason for a democratic society to seek universal access to modern telecommunications. There are also good economic reasons as well to ensure widespread access by *individual* members of communities to the communications networks, particularly the telephone network. For example, public emergency services — police, hospital and fire service — can be delivered more quickly and effectively and at lower cost when households have quick and easy access to telephone services. In addition, there are *network externalities*, meaning that broadening the communications network helps not only the newcomers but also those already on the network by enlarging the circle of people with whom they can communicate. For all these reasons, many countries have set near-universal access to telecommunications services as a policy goal.

Achieving such widespread access to telephone service is expensive for two reasons. First, some customers have such low incomes that even modest telephone charges are unaffordable. In the United States, programs designed to subsidise telephone service to low income customers are called 'lifeline service' programs. Second, the fixed cost per customer of installing access lines to remote areas with low population density is very high. For example, establishing service to customers living on farms and ranches in rural areas typically requires running long wires through difficult terrain even though only a small group of telephone subscribers is served. Even within urban areas, the costs of connecting different customers to the telephone network can vary among customers by a factor of ten. Programs designed to pay part of the cost of providing service to high cost areas are called ‘universal service’ programs.

In practice, implementing a program of universal, affordable access to basic telephone service involves first establishing what is to be included in the ‘basic telephone service’. What options should be available? What level of quality should be maintained? Second, an affordable price must be established. Third, a service provider or providers must be identified, and a means must be found of footing the bill.

In the United States, universal service has been implicitly subsidised both through reduced prices for basic telephone service supported by higher prices for other telecommunications services and through the use of uniform telephone rates over wide areas. In California, for example, even today, anyone in the area serviced by the largest telephone company, Pacific Bell, can purchase basic telephone service for $11.25 per month. This price is the same for hillside dwellers in remote mountain communities as for residents of large apartment buildings in downtown Los Angeles, even for apartments that are just a block away from the main telephone switch. The phone company’s cost per phone line of hooking the apartment and its residents into the system, though, is much lower than for the mountain dwellers, because a single short high capacity wire can be used to provide service to all of the large building’s residents. The implicit subsidies in the system are enormous: one estimate for the subsidy to rural service alone is about $5 billion per year[1] and the estimated size of all rural and urban subsidies is higher still.

So long as local telephone service is provided by monopolies that are free from competitive market constraints, this system can be sustained. In recent years, however, the local telephone monopolies have come under siege. New phone companies have sprung up to offer services in places like Manhattan (initially for business customers), where the high density of telephone lines makes the average cost of service quite low. In the United States, the passage of the *Telecommunications Act* 1996, which aims to reduce regulation and increase competition in telecommunications, is destroying the monopolies at the foundation of a system of uniform local service prices for all customers. The Act provides for the establishment of a fund to subsidise service to customers in high-cost-of-service areas. The Act also requires that the subsidy levels in each area be adequate to cover the universal service provider’s costs.

It is now the task of regulators to decide how to implement the Act’s provisions, keeping in mind the two main goals of encouraging competition in

1 *What Price Universal Service?: Impact of Deleveraging Nationwide Urban/Rural Rates*, Telecommunications Industries Analysis Project, Cambridge, MA., 1993.

the provision of telecommunications services and keeping down the cost of subsidies (and the taxes needed to support them), as well as subsidiary goals like reducing the need for ongoing regulation.

With these goals in mind, two main kinds of policy options have been discussed. The first calls for the use of an auction in which bidders name the price they require to accept a universal service obligation in a service area. This means that the selected suppliers stand ready to offer a prescribed basic service package at a prescribed ‘affordable price’. The advantage of this option is that competition among would-be universal service providers could drive down the necessary level of subsidies. Also, once auctions are conducted, there would be no further need for cost studies to determine appropriate levels of subsidy to a monopoly telephone supplier. Nevertheless, this option is often regarded as unsatisfactory because it results in a single provider in each service area. With neither competition nor regulation to discipline the single provider, there would be little pressure on it to introduce new services and maintain high standards of quality. Also, new telephone providers may be able to bring valuable new services, like cheaper long-distance calling, or packages including telephone service with wireless or cable television services. Having a single provider denies these potential new services to customers.

The second option calls for estimating the costs of providing basic service in each area and then making that level of subsidy available to any company that is willing to accept a universal service obligation for the area. This makes competitive entry relatively easy, with all the advantages that competition entails. However, it has two big disadvantages. First, because it bases subsidies on the existing wireline technology and ignores the revenues from new services that might be delivered over the telephone network, it locks in the subsidies at an unnecessarily high level. Second, it requires ongoing regulatory intervention in the form of both cost studies (to meet the legal and practical requirement that subsidy levels are adequate) and coercive service requirements on the incumbent telephone company at the established subsidy levels.

Each of these options has advantages and disadvantages. Across the United States, the conditions of entry vary as well, with some areas already home to local telephone competition and others where the prospect of competition seems distant. These combined facts raise some obvious questions: Is it possible to tailor the regulatory system to the local conditions? Is there a system that does that automatically, without the need for an omniscient regulator to choose the proper regulatory intervention? Is there a mechanism that is demonstrably optimal for the universal service problem in such varied environments?

10.2 An optimal auction mechanism for universal telephone service

In the process of answering these questions, our analysis introduces an important new alternative into the policy debate. This is an alternative in which the number and identities of the competitors is determined by the market process itself, rather than being set by fiat as in traditional auction proposals. In particular, the new mechanism promotes different market structures in different geographic regions, as is certain to be appropriate given the very different cost conditions that prevail in different areas. Compared to the older proposals, the new alternative is more balanced in encouraging competition both ‘in the market’ after the auction, to promote better service and more variety, and competition ‘for the market’ in the auction, to reduce the level of subsidies that need to be paid.[2]

Because the actual situation in supplying universal telephone is so complex, the theoretical analysis advanced here aims only to capture a few of the most important features of the real situation. We begin by specifying the objective of the whole exercise, which is to maximise a ‘total welfare’ criterion or objective consisting of three terms:

Expected Benefits to Consumers

+ *Expected Profits Enjoyed by Service Providers*

– *Expected Subsidies Paid to Providers*

The first term is the benefits enjoyed by the consumers in an area, which depends on the level of competition in the local telephone market. More competitors vying for customers can lead to various benefits for consumers, including more variety, better service offerings, and more responsive service. More competitors may lead to lower prices, too, if splitting the market does not increase costs too much. To account for the interests of telephone company shareholders, we add the firm’s profits to the social objective.

These two initial terms, however, do not include all the economic benefits and costs. The taxes or surcharges used to pay universal service subsidies distort choices made in the economy and result in a loss of welfare. For example, if universal service were funded by a tax on long-distance calls, that could result in fewer such calls being made — calls that would be made if the price of long-distance calling were not made artificially high by the additional tax. The welfare loss from such distortions is approximately proportional to the total subsidies paid; it is captured by the third term in the formal objective.

2 See Dana and Spier (1994) for a closely related analysis.

To simplify the problem for this presentation, we make a number of assumptions whose significance we discuss briefly at the end of this lecture. We focus on the case where there is a single region in which universal service is to be provided and where all subsidies are paid in the form of a lump sum. There are assumed to be N bidders indexed as i=1,...,N.

Each of the bidders has a cost 'type' $_i$ that determines its cost of providing service to some or all of the customers in the service area. We may think of lower values of $_i$ as corresponding to lower total and marginal costs for firm i allowing it to earn greater profits in any particular competitive situation. Let denote the N-tuple ($_1$,..., $_N$). Let ^{i}(,S) denote the profit earned by firm i when the set of firms receiving subsidies to accept the universal service obligation is S and let B(,S) denote the benefits enjoyed by consumers. We assume that (1) both consumer benefits B(,S) and each firm's operating profits ^{i}(,S) are independent of the types ($_i$,i S) of the firms not actually present and providing telephone service, (2) a firm can earn profits only if it is authorised to supply subsidised service, that is, ^{i}(,S)=0 if i S, (3) ^{i}(,S) is continuously differentiable in $_i$, and (4) for all and all $i \in S$, profits are decreasing in $_i$: $^i_i(,S) \equiv \frac{\partial}{\partial \ _i} < 0$ and non-increasing in the set of competitors S.

The auction that is implemented, including the rules for the kinds of bids that can be made and the way firms behave in the auction game, determines which firms will receive subsidies in exchange for bearing the universal service obligation and what subsidy payments they will receive. The actual outcome of the auction cannot be predicted in advance because it depends, of course, on the cost types . One can describe the likely outcomes by a set of functions which express the probabilities p_S( ) that S will be the set of firms selected to be suppliers when the cost types are given by and the corresponding expected levels of subsidy payments x_i( ) to each firm i. With the outcomes described in this way, the corresponding expected level of welfare, given , is:

$$\sum_S p_S(\ )B(\ ,S)+\sum_S p_S(\ )\sum_{i\in S}\ ^i(\ ,S)-\ \sum_{i=1}^N x_i(\ ).$$

The three terms in this objective correspond to the consumer benefits, profits and burden of taxation term in the welfare calculation.

The expected value of the welfare measure is to be maximised by choosing functions p_S( ) and x_i( ) (i=1,...,N) corresponding to a feasible auction and associated bidding behaviour. For the expected value calculation, we assume that the $_i$s are independent and distributed according to distribution functions F_i with corresponding densities f_i, i=1,...,N. Thus, expected welfare is:

$$\int \left[\sum_{S} p_S(\ ) \left(B(\ ,S) + \sum_{i \in S} {}^{i}(\ ,S) \right) - \ \sum_{i=1}^{N} x_i(\ ) \right] f(\ ) d\ .$$

In order to characterise the maximum in this problem, one first must characterise the constraints on the p_S and x_i functions that are implied by our postulates concerning how the bidders will behave. We assume that the bidders will play the Nash equilibrium strategies of whatever auction game we may design and, if there are multiple equilibria, that the bidders will play the equilibrium selected by the mechanism designer. To solve the maximisation problem, we utilise techniques first developed in the Roger Myerson's 1981 analysis of auctions that maximise the seller's expected revenues.

The full details of the mathematical analysis will not be reported here. What Myerson's analysis demonstrates is that the p_S functions combined with the avoidance of unnecessary subsidies to losing bidders combine to determine uniquely the necessary expected subsidy levels E[$x_i(\ )|\ _i$]. This allows one to substitute for x_i in the objective function, rewriting it as the expectation of the following alternative objective function:

$$\sum_{S} p_S(\ ) V(S,\ )$$

where

$$V(S,\ ) = B(\ ,S) + \sum_{i \in S} \left((1+\ )\ {}^{i}(\ ,S) + \ {}^{i}_{i}(\ ,S) \frac{F_i(\ _i)}{f_i(\ _i)} \right).$$

The function $V(S,\ )$ is called the "*virtual welfare*" function. We limit attention here to what we may call the "regular case," which is characterised by two assumptions about the function $V(S,\ )$. The first is that it is more attractive to add low-cost types $\ _i$ than high cost types. We write this as a "decreasing differences" condition: $V(S \cup \{i\},\ )$-$V(S,\ )$ is decreasing in $\ _i$. The second condition is that firms and types may be ranked by an index such that *V*-maximising collection of firms consists of some number of firms with the highest index values. Various particular assumptions may be made which imply this structure. The upshot of the analysis is the following:

> ***Proposition:*** *In the regular case, an auction design is optimal if and only if it results in outcomes in which (1) for almost every ,* $p_s(\ )=1$ *for the S maximises V(S,) and (2) the expected net profits (gross profit plus subsidy) of the highest cost types are zero.*

A striking aspect of the optimal auction is that it calls for the market structure to be *endogenous*. This means that the *number* of firms participating in the market may depend on the firms' cost characteristics, which are the private information of the various firms. If there are several independent regions in which universal service is to be supplied, the result is that different numbers of competitors may be present in each, according to the privately known cost information of the firms.

In determining the optimal set of firms to include in the market, the profits of the firms are given extra weight in the virtual welfare function compared to the original social objective: it is multiplied by 1+ . In addition, $V(S, \ )$ includes terms (F_j/f_j) to account for the bidding incentives of the firms. Awarding universal service subsidies to many firms tends to reduce the incentive of each firm to bid aggressively, since even a less aggressive bid is more likely to result in a reward. Therefore, unless there are diseconomies of scale (which is unlikely in practice), one consequence of designing an auction to allow multiple universal service providers is higher average subsidies. An optimal auction design takes that effect into account, typically reducing the number of firms both to increase pre-subsidy industry profits and to increase the intensity of competition “for the market.”

Although the first part of the Proposition identifies quite specifically the criterion for who the winners in an optimal auction should be, the Proposition does not specify a unique rule for how payments should be made. Rather, the second part of the Proposition specifies only that high cost types should expect zero profits, that is, that no unnecessary subsidies should be paid.

The multiplicity of optimal payment rules means that there is scope for using the payment rule to pursue secondary objectives. One such objective is to arrange that each bidder has a *dominant strategy*. The advantages of dominant strategies were first identified by Vickrey (1961), who emphasise that these simplify the bidders problem, avoiding potentially costly errors and providing no incentive for bidders to make wasteful expenditures trying to guess each other’s bids. The basic rule for making truthful reporting of cost data a dominant strategy is also one that Vickrey (1961) had identified. One achieves that by “paying each seller for his supply an amount equal to what he could extract as a perfectly price discriminating monopolist [against the residual demand curve]”. In this case, the analogous rule is as follows: For each , pay firm j a subsidy that makes its post-subsidy profit equal to the increase in the maximal value of the virtual welfare function, $V(S, \ )$, that results from expanding the set of available firms $N\backslash\{j\}$ to N. This rule implements the allocation identified in the Proposition, and makes truthful reporting a dominant strategy.

Another possible secondary objective is to pay uniform subsidies to all subsidised universal service suppliers. There may be legal reasons to prefer uniform subsidies. Uniform per subscriber subsidies may also be desired because they avoid advantaging any particular competitor when the competition for customers begins. Although uniform subsidies are possible, it is not possible to achieve both uniform subsidies and dominant strategy implementation of the optimal auction.

10.3 Limitations and possible extensions

The foregoing analysis is a preliminary one that is valuable because it introduces a new option. However, the recommended solution is only as good as the underlying model. The model itself has several limitations.

One of the most important assumptions of the model is that subsidies are paid in the form of a lump sum, regardless of the number of subscribers served. In reality, lump sum subsidies have some undesirable incentive properties. Bidders have weaker incentives to provide good service if the subsidies are independent of the number of customers served. Indeed, because subsidies are needed only for high-cost customers for whom service is unremunerative, it is necessarily wrong to suppose that service would be provided at all, let alone at the same level, if subsidy levels were low. To put the point more generally, the level of subsidies is likely to affect the intensity of competition among suppliers, and the existing model fails to account for that.

A second potentially important omission concerns variations in costs among customers in the area of universal service. If the cost variations are large across the service area, firms may be tempted to offer service only to the customers in the lowest cost segments of the service area. That problem could be resolved by running auctions for smaller, more homogenous areas, and indeed such a proposal has been made in the United States. However, if small service areas are specified for the auction, it may be inappropriate to consider the costs of service separately for each area, because there could be important shared costs among them. As of the date of this lecture, the importance of such shared costs for universal service remains an open question.

A third point concerns how the auction will operate when some of the service providers purchase some of their inputs from an incumbent telephone company. In the United States, the law governing local competition requires the incumbent to provide unbundled network elements at regulated prices, which confounds the question of whether the auction can help to identify the low-cost providers.

Fourth is the need to account for possible dependencies among areas in designing the auction. One significant possibility is that the cost of serving a set of adjacent areas is significantly reduced when a single firm serves them all. In that case, there are two practical approaches possible. The first approach treats the several areas as a single unit. That works tolerably well when the same groupings are appropriate for all the bidders. The second approach is more complicated but also more flexible. It involves allowing bidders to specify bids for combinations of areas and then selecting winners to take account of these economies of scope. Auction designs like that are still novel and unproved, but some promising designs are currently being tested for other applications.

Finally, during the transition to competitive provision of local telephone service in the United States, the incumbent local exchange carriers continue to have a special obligation to offer service. The analysis suggested here has been vague about the details of how the transition will be made. The timing of auctions in different service areas could be important, as could issues about the relation of the auction rules to other local competition rules. All of these details need to be worked out carefully if universal service auctions are to be successfully implemented.

10.4 Conclusion

Competition in providing local service has made obsolete the old model of a monopoly providing service at a uniform rate over wide service areas. Yet, for a wide variety of political, social and economic reasons, it is desirable to have affordable service even to relatively remote communities. Up to now, the ways of achieving that goal have either involved continued regulation or an auction that preserves monopoly supply status for some firm.

Our new proposal combines the advantages of an auction scheme, in which bidding keeps burdensome subsidies low and avoids the need for detailed price regulation, with those of a fixed price free entry scheme, in which the number of entering firms depends on market conditions. Although many details remain to be specified, this approach offers the promise of a mechanism that can be applied flexibly to balance the several conflicting objectives in establishing a universal service plan.

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PLENARY SESSION 1

Invited paper 11

Spectrum property rights and practical auction design: the Australian experience

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11.1 Introduction to spectrum management

Radiofrequency spectrum

The radiofrequency spectrum is that part of the wider electromagnetic spectrum that can be used for radiocommunications, that is, communication by radio. The radiofrequency spectrum is at the low energy end of the electromagnetic spectrum. The electromagnetic spectrum also covers infrared radiation, light, ultra-violet radiation, X-rays and, at very high energies, gamma rays.

The *Radiocommunications Act* 1992 (the Act) defines *spectrum* as ‘the range of frequencies within which radiocommunications are capable of being made’. The Act further defines a *radio emission* as ‘any emission of electromagnetic energy of frequencies less than 420 terahertz without continuous artificial guide’.

Because the radio emission is radiated freely (not guided) it must be managed so that two signals with the similar or complementary characteristics can not be received at a receiver at the same time. When two or more signals are available at a receiver at the same time, these signals can ‘interfere’ with each other, and the information contained in the signals may be lost.

Coordinating spectrum use to avoid interference between signals has traditionally been done by national governments. Governments have controlled every level of the process, from international coordination at the treaty level, through national planning, individual band planning and ultimately to licence issue and administration. This approach has been cemented in history and, while the traditional justification for such an approach is beyond the scope of this paper, it seems to have been widely accepted that management and planning of the spectrum is fundamentally a role of government.

The planning process

Traditional radiocommunications planning and licensing is based on a hierarchical structure of planning powers contained in the Act. At the highest level, it involves Australia’s participation in the international community, through the International Telecommunication Union (ITU). The ITU facilitates international agreement about how use of the spectrum will be coordinated to minimise the potential for interference between nations. The ITU is an organisation under the umbrella of the United Nations, and nations gain the benefit of the negotiated positions it develops by agreeing to be subject to ITU treaty obligations. The ITU's negotiation process is centred on the World Radio Conference, which takes place every two years.

At the next level of planning is the Australian Spectrum Plan, the central planning instrument under Australian law (SMA 1997). This plan divides the spectrum in Australia between specific uses, for example, fixed services, mobile, broadcasting, satellite, defence**,** scientific and other uses. The Australian Spectrum Plan generally follows the assignment of spectrum developed in the international community, to which Australia accedes by treaty. The process for making and varying the Australian Spectrum Plan is typically protracted. Variations are subject to public consultation with affected users and this can take many months.

Band plans form the next level of the planning hierarchy. Band plans set out how a band identified for a specific use in the Australian Spectrum Plan will be managed. Band plans make provision for specific types of services, and establish a framework under which these types of services can be licensed. A Band Plan must be compatible with the Australian Spectrum Plan. Band plans are also prepared following a process of public consultation. While there is provision for making a band plan without consultation, the decision to do so would be hard to defend at law unless making the plan in this way was necessary for order and good government.

At the bottom of the spectrum management hierarchy are licensing plans and policies, articulated through instruments called Radiocommunications Assignment Licensing Instructions. These are administrative instructions that codify operational practice about how licences can be assigned in particular bands.

Making provision of a new technology might typically involve:

- consideration in the international community of an appropriate band for the deployment of that technology which may delay the change for two or more years;
- consideration of whether and how to adopt the change in Australia, which may then lead to preparation of draft amendments to the Australian Spectrum Plan, and then public consultation on those amendments;
- following finalisation of the spectrum plan, preparation of a band plan, consistent with the spectrum plan, which makes provision for the new service, and sets out how incumbent users will be treated (for example, will the plan provide for non-renewal of existing licences?); and
- finally, once all the plans are in place, individual licensing of services, on a case by case basis, carefully coordinating the new services with any incumbents whose licence allows them to remain.

By the time this process has taken its course, it is possible that a newer and possibly better technology may be on the horizon. This effect is perhaps illustrated in the field of computing. The remarkably predictive ‘Moore’s Law’ suggests that the logic density of a constant sized silicon chip will double every year. The convergence of communications and computing means that Moore’s Law is of increasing application to communication systems. The central planning model, based on a timing window of — between two and five years is becoming less able to keep up with the roll-out of new communications/computing technology, which is taking place at roughly double that rate.

11.2 The public policy review

Background to reform

Electronic communication is fundamental to virtually every sector of a modern industrialised economy. The communications sector is one of the fastest growing sectors in the Australian economy (ABS 1997).

Acceptance of the importance of communications to economic activity has led to the radiofrequency spectrum being increasingly regarded as a national economic resource that needs to be managed efficiently for the greatest good of the nation.

The specific recognition of the economic value of spectrum came about against a background of microeconomic reform in the period from about 1987 to 1992. During that period, the telecommunications, radiocommunications and broadcasting regulatory regimes in Australia were all systematically reviewed as part of a wider government impetus for microeconomic reform.

The model of review and reform adopted by the Department of Transport and Communications (from which the Australian Communications Authority (ACA) can trace its roots) included economic review of existing regulation by the Bureau of Transport and Communications Economics (BTCE); a research bureau within the Department (Evans 1992). In some cases, the review process also included a formal reference from the Government to the House of Representatives Standing Committee on Transport Communications and Infrastructure (HORSCOTCI) to conduct a Parliamentary Inquiry, as a way of exposing the policy issues to wider public scrutiny.

After the public review processes had identified the policy issues, the Government and its advisers set about developing public policy responses to the issues, and coordinating these responses across agencies. Once the Government had set the policy framework, it was translated into draft legislation for consideration by the Parliament. In the case of radiocommunications, this review process culminated with the passage of the *Radiocommunications Act* 1992.

Bureau of Transport and Communication Economics Review

The BTCE's report into radiocommunications (see BTCE 1990) was the first systematic review of the Australian approach to managing the radiofrequency spectrum resource to approach the issues from an economic perspective. After considering the existing planning, licensing and fee setting activities, the BTCE identified widespread inefficiency in many aspects of spectrum management in Australia, all of which flowed from the application of the central planning model. These findings are summarised below.

The administrative system:

- *failed to accommodate changing demands and thus produce socially optimal outcomes*

  From the analysis of spectrum use undertaken by the BTCE, it was evident that the supply of spectrum for specific uses, through the planning process, had not resulted in an even distribution of occupancy. Avoidable mismatches in supply and demand led to obvious efficiency losses. Not only could sections of the spectrum left lying idle be used to provide more services, but additional costs borne by users in congested bands could also be avoided by their relocation to less congested spectrum.

  Mismatches of this kind occur because administrators are forced to anticipate technological and market developments in an environment of rapidly changing communications technology and user demand. No government agency can reliably predict public demand for specific services or the future direction of new technologies. Even if technology and the public's needs were unchanging, a central planner could only imprecisely evaluate the benefits of the myriad possible uses of spectrum and determine which frequencies should be used. for each service.

- *provided limited mechanisms to potential users to obtain existing assignments*

  Further inefficiencies in spectrum use resulted from assigning spectrum to users on a 'first come, first served' basis, combined with virtual use in perpetuity. This meant that there were limited mechanisms for potential users to obtain existing assignments, other than to wait for frequencies to be relinquished or to purchase the company holding the licence. Such an approach tended to favour established applicants. If latecomers are more efficient but are unable to gain access or must accept lower quality access, the outcome is reduced economic efficiency.

provided no scope for individual users to negotiate among themselves to determine acceptable levels of interference

The BTCE pointed out that under the traditional administrative system, the maximum acceptable levels of interference for signals were preset by the central planners on technical grounds, usually to the point where interference was almost non-existent, with no allowance for the economic cost of this approach. Under such a system, there is limited opportunity for individual users to negotiate among themselves to share spectrum, to determine levels of interference they deem acceptable, or to choose the equipment which they deem appropriate.

had a pricing structure that failed to effectively control demand

Although some regard was given for setting the ‘price’ to balance supply and demand, the BTCE showed that such adjustments were not sufficient to achieve equilibrium. The BTCE noted that the current system fell short of the goal of rationing spectrum in the most economically efficient manner, largely because of inadequate flexibility to meet changing demand patterns. The BTCE also noted that the supply of spectrum to specific uses, as managed through the planning process, has not matched demand.

The BTCE’s proposed solution was to introduce a market-based model of spectrum management, and to substantially reform the administrative aspects of licensing, especially with regard to licence fees. The BTCE argued that an economically efficient solution would be to allow for a trade-off between the number of services and the quality of signals in accordance with changes in demand patterns, technology and methods of operating cervices (BTCE 1990, p.xviii). The BTCE suggested that the market price mechanism would ration spectrum, and those who paid the highest price would be those who placed the highest value on the resource as an input to production.

In order for such a system to work, the BTCE noted that it would be necessary to establish a legal framework which conferred *property rights* to spectrum access, regulated trading, facilitated the resolution of trading, and accommodated public and merit goods.

Since the early l950s, the idea of property-like rights in radio spectrum has been popular with a wide range of economists and policy analysts (Hazlett 1995). A number of definitions have been developed and proposed as a means of creating spectrum property rights. Essentially, they all rely upon defining spectrum access in three dimensions: time, geographic area and spectrum channel. A user would have the right to transmit during particular hours of the day, in a specified geographic area, within a specified spectrum channel width, provided that the signals did not exceed certain levels outside the geographic area and spectrum channel. The user would be able to vary the uses and technical parameters within those rights. The BTCE proposed a model which relied on the creation of 'spectrum access rights' (SARs) which drew heavily on these fairly classical ideas. The BTCE saw a SAR being defined in terms of:

- permitted use;
- time of day of use;
- the frequency band authorised;
- the geographic area; and
- power levels at the spectrum and geographic boundaries.

The implementation of the model required the:

- creation of SARs with fixed non-renewable terms;
- conversion of existing assignments to SARs;
- open trading in, and leasing of, SARs;
- provision for amalgamation and subdivision of SARs;
- auctioning of SARs where appropriate;
- allocation of SARs over the counter in other cases at a price determined by efficient pricing principles; and
- cost recovery of direct charges.

Interestingly, the BTCE seemed unwilling to question the central planning model's expectation that parts of the spectrum should be dedicated to particular uses, because it acknowledged that

> SARs would be defined in terms of the **permitted uses,** the time of the day, **spectrum channel width,** geographic area and the power levels at the spectrum end geographic boundaries [emphasis added](BTCE 1990, p.xix)

and

> Through the market system, users and spectrum lessors would be encouraged to vary uses **(within prescribed uses)** to allow for increased participation of users in spectrum planning [emphasis added] (BTCE 1990, p.77).

The BTCE envisaged that the SAR holder could determine a particular use or uses (within the prescribed uses) and the number of services. A government regulatory agency would be responsible for determining interference levels and settling interference disputes, but under a less rigid approach than was being applied at the time. Single use SARs would be available where there were social or technical reasons to designate permissible uses.

Open trading and leasing of SARs would be permitted, but amalgamation and subdivision of SARs would require the approval of the regulatory agency. There would be a legal register of ownership similar to the registration of land titles. Sale prices would be recorded so that users, spectrum lessors, potential users and interested parties could monitor the market.

Where feasible, the BTCE recommended that auctioning be used to sell any unused spectrum. Newcomers wishing to acquire SARs in congested areas, whether for an existing use or a new use, would need to purchase them from existing users. Where auctioning was not possible, SARs would be sold over-the-counter at a price equal to the administrative cost of issuing the SARs. An annual charge would be applied to all SAR holders to cover the costs to the regulatory agency, and not recouped through other more direct means.

The BTCE suggested that this framework would create an environment that would maximise the net returns realised from spectrum access. A market in spectrum access through SARs, together with auctioning and an appropriate pricing system, would ensure that spectrum would be considered an asset from which users would attempt to maximise their return. The users who expect to obtain the highest net returns would gain access and they would have incentives to manage their SARs to produce these benefits. This would be a dynamic process, as the net benefits from different uses, equipment and practices changed over time.

The BTCE proposed that SAR holders would have the legal right to transmit and to be free from interference within these boundaries. The advantage of such a system would be that it would allow spectrum users much greater autonomy over the design and siting of devices, effectively taking over the licence assignment role traditionally undertaken by government In this model, government would still be responsible for international coordination, national spectrum planning and, to the extent that use was necessary for particular bands, the Government would also be responsible for band planning. The primary efficiency gain in the BTCE model resulted from the use of market mechanisms as a licence allocation tool.

SARs could be traded in the BTCE model, but the BTCE envisaged what we regard today as a very limited form of trading.

> Buying, selling and sub-leasing of all SARs (radiocommunications and broadcasting) would be through an open market system. If the SARs were sold,

> the new holder would be restricted to the condition relating to prescribed uses, the time, spectrum and geographic dimensions and the interference parameters.
>
> ... However, if holders wished to amalgamate or divide SARs in time, spectrum or geographic dimensions for separate sale, approval would be required, as this would change the interference parameters. (BTCE 1990, p.83)

This last sentence brings out what, with hindsight, seems to be the biggest limitation in the BTCE’s approach — that the interference management framework would always be dictated by the hierarchy of planning instruments, and that trading of spectrum as a resource would have to be constrained by determining spectrum ‘use’.

The BTCE worked through the application of SARs at an economic level and described how SARs would permit the management of spectrum by private companies, effectively breaking the government monopoly on every level of management. The BTCE’s model suggested that in congested areas, blocks of spectrum could be sold as SARs to new owners who could lease access to that space to other users, effectively in direct competition with the central government agency.

The BTCE acknowledged a number of criticisms of the model, but essentially these criticisms were from the point of view of economic theory and the BTCE was able to address them. At no stage, however, did the BTCE actually consider the practical implementation of such a model. It is worth noting that while the BTCE acknowledged that the classic property rights model had existed in the literature for some time, at the time of the BTCE paper no one, other than the New Zealand Government, had attempted to implement such a thing.

House of Representatives Standing Committee on Transport Communications and Infrastructure Report

On 23 July 1990, the Minister for Transport and Communications at that time, the Hon. Kim Beazley MP, requested the HORSCOTCI to hold a public inquiry into the efficiency and effectiveness of spectrum management arrangements in Australia. The BTCE economic review formed an important reference document to the inquiry.

The Committee tabled its report, entitled *Management of the Radio Frequency Spectrum*, in Parliament on 17 October 1991. The Committee considered evidence in over 70 written submissions and at six public hearings, representing the views of commercial and non-commercial spectrum users and industry associations.

The HORSCOTCI's main conclusion was that the existing administrative system of spectrum management would not provide an efficient or effective means of addressing Australia's long-term spectrum requirements.

The Committee recommended the introduction of a mixed administrative/market-based system of spectrum management involving the gradual commencement of trade in spectrum resource and the fine-tuning of the current administrative system.

In general, the HORSCOTCI agreed with the conclusions of the BTCE regarding inefficiencies in the management of spectrum. It highlighted these as:

- dynamic efficiency — highlighting that current practices lack flexibility and timeliness with regard to changing demand for spectrum;
- technical inefficiency — concluding that the Department of Transport and Communications was constrained in its ability to ensure that the most efficient equipment and practices are in use;
- efficient provision for public and merit goods — highlighting the need for efficient use of spectrum, particularly with respect to public sector uses; and
- allocation of spectrum to the highest valued use — noting that the current system could not do this, and that this would become a critical issue if demand continued to increase and congestion became more commonplace.

The HORSCOTCI also concluded that the current approach to levying charges had little effect in managing demand, did not promote efficiency, and was not transparent to users.

The Government tabled in Parliament an interim response to the HORSCOTCI report in December 1991, followed by a full response in September 1992. The Government adopted many of the HORSCOTCI recommendations as a basis for spectrum management reform.

In line with the HORSCOTCI recommendations, the Government adopted a spectrum management reform strategy involving:

- the selective and progressive introduction of a market-based system of spectrum management to operate in defined spectrum segments alongside the administrative system;
- improvements to the efficiency and effectiveness of the administrative system; and
- the establishment of the Spectrum Management Agency (SMA).

These reforms were enacted by the Parliament in the *Radiocommunications Act* 1992.

11.3 Implementing spectrum property rights

At the time the SMA was created in July 1993, the law provided for *spectrum licences* as a form of property-like right. At the time, however, the Agency had little idea about how to implement such a thing. There was theory and there was law, but there was no practice. The SMA's own engineering and technical staff saw major difficulties standing in the way of implementation.

The Spectrum Marketing Team (SMT) was created as a multi-disciplinary team, tasked to implement spectrum licensing and implement the law.[1] The SMT produced a number of discussion papers that explored the issues in setting an engineering framework for spectrum licensing to manage interference. These papers were accompanied by a series of case studies developed to explore how these concepts might work in an operational setting. It is fair to say that the papers and the concepts embodied in them were politely considered within industry, but were generally treated with suspicion. It seemed to many that spectrum licensing was incapable of being implemented, and indeed the view of some in the radiocommunications industry was that it should not be implemented.

Notwithstanding the critics, the goal of the SMT has been to implement, within the law, a fully traceable, technology-neutral spectrum access right that allows market mechanisms to not only allocate the spectrum resource between users but also to allow those users to select their own technology.

The problem

To many people in the newly created SMA, the ideal of a spectrum property-like right which placed planning and licensing in the hands of the 'market' (with its perceived attendant evils) seemed fundamentally disempowering. Many staff believed that the concepts articulated by the economists could *not* be implemented, because these concepts ignored the physical properties of radiofrequency radiation. Suspicion of spectrum licensing was not helped by the limitations of the model proposed by the BTCE in dealing with practical radiocommunications. That model seemed to fit uncomfortably with the laws of physics. There seemed to be no acknowledgment in the model of the mechanisms needed to properly manage interference, and so maximise spectrum utility. Indeed, it is my view that the classical spectrum property model, articulated by the BTCE and implemented literally in the *Radiocommunications Act* 1992, is in many ways incomplete. The implementation of true spectrum property-like rights requires a number of

[1] I was recruited to lead SMT in October 1994.

additional and far more complicated mechanisms than provided in the BTCE's SAR model.

Concerns about the BTCE SAR Model

By creating rights in area, time and frequency bandwidth, the SAR model requires the creation of exclusive rights in a four dimensional continuum (time, frequency and two dimensions describing area).[2] The task for the regulator centres around developing a licence system (and therefore a recording system) that is capable of recording and maintaining exclusive access in these four dimensions. This is no trivial matter.

The model also relies on imposing 'limits of power levels at the geographic and frequency boundaries', which poses a significant problem for the regulator! In the event of a complaint, the regulator has to establish *as a matter of fact* whether or not the power level has been breached. As our engineering and field technical officers were quick to point out, many phenomena in radiofrequency propagation lead to situations where power levels *cannot be measured accurately*. Indeed, there are situations where power levels measured only metres apart may be substantially different! The idea of absolute and measurable power levels at boundaries is unworkable. Many other technical considerations that directly affect the utility of spectrum and the management of interference are ignored in the BTCE model, including issues associated with costing devices, management of inter-modulation products, deployment constraints for duplex operations and so on.

The SMA's challenge was to develop an engineering framework to support our objective for spectrum property rights that deals with all of these issues, within the framework provided by the law. These issues have now been solved by the SMA and the mechanisms published (SMA 1996). The detailed engineering behind them is beyond the scope of this paper, but it relies essentially on a sophisticated terrain model[3] and geographic information system capabilities to make reasonably accurate predictions of propagation loss. These predictions are used to establish a theoretical *device boundary* for a proposed device (Whittaker and Yang 1997). Provided that the device boundary of a proposed device falls

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2 While the spectrum space is four dimensional, the SMA found it convenient to ignore the time dimension as an aid to understanding. Three-dimensional space is much easier to conceptualise than four-dimensional space.

3 This digital elevation model, called RadDEM, has a resolution over all of Australia of nine seconds of arc (about 250m, depending on latitude). RadDEM has been published on CD ROM and is available for purchase from the ACA.

wholly within the geographic and frequency bandwidth boundaries of the licence, then the device is deemed not to cause unacceptable interference. This gets the regulator out of the difficult issue of having to measure power levels at boundaries. Even using these sophisticated models and techniques, it is not possible to totally remove the incidence of interference. Indeed, the model actually *requires* a small probability (about 1 per cent) of actual interference occurring in the field, because this provides some feedback about the level of spectrum efficiency within a band. Too little actual interference being reported, and the spectrum utilisation authorised by the technical framework might be too low. Too high a level of actual interference would indicate too liberal a regime.

Turning the dream into reality

While most of the attention of industry concerned the development of an engineering framework for managing interference that fitted the laws of physics, the central issue of how to manage a property-like right with enforceable boundaries in something as abstract as radiofrequency spectrum remained unaddressed.

The first hint of recognition that a solution might be at hand came in March 1995, when the SMA released its public discussion paper *Implementing Spectrum Licensing*. In that paper, while addressing the issue of how spectrum might be marketed (that is, how parcels of spectrum space might be defined and allocated) the SMA suggested three approaches:

- an approach which authorised use of spectrum to the full limit of the designated band, over all of Australia;
- a service-related approach which sub-divided a band into packages that were designed to cater to certain services types and/or communities of interest (not unlike existing practice in the broadcasting sector); and
- a modular approach, which sub-divided the band into standard blocks which could be aggregated in response to market conditions to cater to individual licensee preferences (SMA 1995, pp.24–26).

To promote flexibility, and so deal with the deficiencies identified by the BTCE and the HORSCOTCI regarding the lack of flexibility in the existing system, the SMA openly favoured the modular approach. The feeling was that this might open the way for the market to influence decisions about spectrum use, taking reform much further than the BTCE contemplated and into the spectrum plan/band plan area.

The modular approach sees spectrum being sub-divided in area and bandwidth into small and arbitrary commodity units of spectrum space. Utility comes not so much from the blocks themselves but from the ability to aggregate the blocks, either in coverage area, or in bandwidth to provide increased coverage, or increased bandwidth, or both.

In early thinking, the SMA conceived these blocks being hexagonal in area, following standard engineering practice that planned for spectrum re-use on a hexagonal cell structure. Hexagons are able to be configured in a regular repeating lattice (like a honeycomb) and loosely approximate a circle, so mimicking the popular analogy for radio waves as being like the ripples created on a pond by a tossed pebble.

On evaluation, however, it became clear that the mythical circular propagation plot hardly ever occurred in nature, mainly because of the effects of uneven terrain loss. It was therefore not necessary for the SMA to use hexagons as an approximation to circles, for circles did not occur anyway. The SMA settled on using squares bounded by parallels of latitude and meridians of longitude. The areas thus created are literally *curvilinear trapezoids*, but can be represented through map projection as squares. The regularity of these curvilinear trapezoids, and their definition in terms of the national spheroid, made mapping and projection a simple matter.

In the frequency dimension, the SMA conceived that a band would be subdivided into blocks of a standard bandwidth. The optimal size of these blocks would be determined by the SMA to satisfy two goals:

- to enable efficient use by the most narrowband service thought to want to operate in the band; and
- to provide a size that provided the lowest common denominator of bandwidth for the variety of possible communication systems in the band.

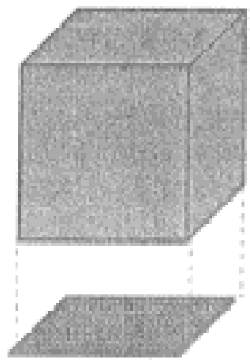
In order to exploit the flexibility that this model provided, the SMA's engineering framework was developed to manage interference at the boundary of these basic units of spectrum space, rather than being developed to reflect a particular use or service as the BTCE model proposed. The advantage of the SMA approach is that it allows the aggregation of spectrum space without affecting the boundary conditions that apply — these remain constant, no matter what technology or system is deployed. In order to accommodate a system that requires a large amount of spectrum space, the engineering framework requires the operator to buy a lot of spectrum space so that the device emissions can always be managed within the standard framework.

The impetus for these ideas came from an operational imperative: *to design a computer database in which to record ownership of spectrum space*. One of the requirements of spectrum licensing is exclusivity of 'ownership', and the challenge was to develop a database structure that allowed conflicts in exclusivity to be identified algorithmically in all four dimensions of the spectrum continuum. The simplest solution was to establish a commodity unit, to which all trading and access would relate. For each commodity unit, there could be only one logical owner.

The commodity unit of spectrum space, when first described, was called a 'smallest trading unit', because that was what it was — the lowest common denominator building block of spectrum space. This subsequently changed over time to 'standard trading unit', or STU for short. STUs are the basic building blocks from which usable spectrum space can be built. By definition, the SMA made STUs finite, indivisible and able to be combined with their neighbours into large spectrum spaces with more utility. Conversely, large spectrum spaces can be disaggregated in the market place in terms of STUs, allowing for the first time commodity trading in spectrum space.

STUs are four-dimensional units of spectrum space. They occupy an area (two dimensions), they have a bandwidth (or frequency range) and they exist in the temporal dimension. To aid understanding, however, the SMA conceived of STUs as cubes (see figure 11.1), with area coverage on the horizontal plane and frequency bandwidth on the vertical axis. Time is generally ignored to aid practical understanding of how spectrum space can be manipulated. A single STU is the smallest unit of spectrum space for which the ACA will issue a licence or register trading.

Figure 11.1 Standard Trading Units



Standard Trading Units are like cubes of spectrum space. In the area dimension, the SMA created a 'spectrum map grid'. This is a grid of parallels of latitude and meridians of longitude that defines 21 998 cells. These cells exist in three separate sizes, depending on population density:

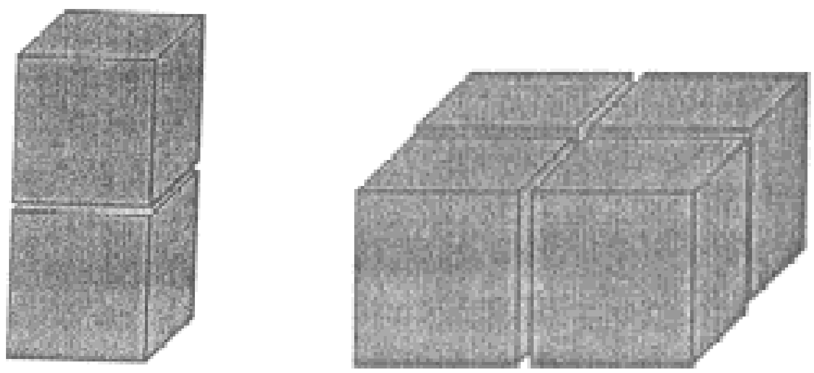
- 3 degrees of arc in remote areas;
- 1 degree of arc in rural areas; and
- 5 minutes of arc in metropolitan and regional areas.

The area of every spectrum licence must be defined in terms of these cells.

Each spectrum licence is an aggregation of a number of STUs that have been combined like building blocks to form usable spectrum space. Licensees have the flexibility to aggregate spectrum access in the marketplace to cover additional areas, or a wider frequency bandwidth (see figure 11.2), without having to return to the ACA for additional spectrum licences. Alternatively, licensees can sub-divide their spectrum access into a number of narrower bandwidth channels, or a number of smaller areas within the main area, or both. This mechanism, more than any other, facilitates market-based responses to the emergence of new technology. A licensee wanting to introduce a new technology can enter the market place and buy the spectrum space it needs directly, without having to wait for the planning cycle to make provision for that technology.

It is important to remember that spectrum licensing does not exist in isolation. There is still a need to register devices that are deployed in the field for each new device contributes to the overall radio environment, and this environment still needs to be managed. There is still a need to ensure that devices, when they are operated, will not create unacceptable interference to devices operating in neighbouring properties.

Figure 11.2 Aggregation of Standard Trading Units



STUs can be stacked vertically (left) to provide increased bandwidth, or horizontally (right) to cover a larger area.

While it is true that licensees are free to deploy any technology, any device, from any site in their licence, it remains the licensee's responsibility to ensure that the device will not cause unacceptable interference. Under spectrum licensing as implemented by the SMA, each licensee has the flexibility to change equipment, antennae, siting or any other aspect of its use of spectrum, provided they comply with the technical conditions of the licence and the engineering framework.

Allocating spectrum licences

With the theory behind a traceable and technology transparent spectrum access right comfortably settled, there remained the significant problem of allocating these rights in a way that did not compromise the objectives of reform. The SMT wanted to exploit the benefits of the modular approach and allow market conditions to determine how arbitrary blocks of spectrum space would be aggregated into the preferred configurations of the market place.

Price-based allocation

The *Radiocommunications Act* 1992 required that spectrum licences be allocated by using a price-based system. The Act defined this as an auction, tender or predetermined or negotiated price. The clear intention was that market conditions should prevail in allocating these licences, rather than administrative pricing, comparative merit assessment, lottery or ballot.

Australian experience with PBAs

In 1993, Australia adopted price based allocation methods for issuing Pay TV licences. The tendering procedures involved the submission of written bids in sealed envelopes, payment of a non-refundable application fee of $500 and a statement of the applicant’s industry plan and the proposed ownership and control structure of the applicant’s operating company.

There was a significant flaw in the rules that underpinned the tendering process. Bidders were not explicitly prohibited from submitting multiple bids for the same licence, nor were they compelled in any way to meet their financial commitments. Licence bidders were able to engage in a strategy of submitting ‘cascading’ bids — that is, a series of bids in descending order of magnitude. This meant that the eventual winner did not pay their highest bid price but some lower amount drawn from their cascading menu of bids. This process resulted in some embarrassment for the Government, and highlighted the importance of careful auction design (Cheah 1994, pp.21–25).

On the creation of the SMA in July 1993, the Agency inherited a requirement to allocate MDS licences that had been subject to an aborted tender the previous year. The SMA chose to allocate these licences using a conventional English (open oral outcry) auction. Despite adopting a conventional auction design, the SMA carefully developed a set of rules aimed at preventing a repeat of the previous experiences. In 1994 and 1995, the SMA successfully concluded auctions for apparatus licences in the MDS bands and generated A$100.2 million from the sales.

While the English auction approach is undoubtedly capable of allocating individual apparatus licences, it suffers an obvious and fatal defect in any situation where an applicant is seeking complementary licences, or in the case of spectrum licensing, complementary components of a licence. In the case of spectrum licensing, it can not meet the expectation to allow market conditions to guide efficient and optimal organisation of spectrum lots into preferred aggregations. This is because an English auction design allocates lots sequentially. Bidders do not know whether they will be successful in obtaining the other components of their preferred aggregation. This weakness was also noted by the SMA for ‘Dutch’ (descending bid) and ‘Vickrey’ (second price) auctions and sealed bid tenders. Each of these designs would have required the SMA to offer properties that reflected the SMA’s own assessment of the likely use, and thus would have prejudged the market. The rational theorists in the SMT hoped for market purity to the greatest extent possible.

The *simultaneous ascending auction* system[4] developed for the United States Federal Communications Commission (FCC) to allocate radiocommunications licences for personal communications services (PCS) seemed not to suffer from this weakness. By offering all lots in parallel over multiple rounds, this design seemed to actively encourage the emergence of market preferred aggregations. It allowed bidders to bid on their preferred aggregations, without the risk of being unable to secure all of the elements of their preferred aggregation.

11.4 Design challenges in the Australian setting

The United States PCS spectrum auctions were essentially two-dimensional auctions, in that aggregation of licences was only possible in the horizontal plane — that is, area coverage. The United States auctions did not really contemplate or permit (through ownership and control limitations) the vertical aggregation of spectrum space to increase bandwidth. The United States auctions were for ‘licences’ following the traditional centrally planned apparatus licence approach.

In the SMA model, however, the goal was to use the auction mechanism to facilitate preferred aggregations in all *three* dimensions of area coverage and bandwidth.

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4 For detail about the development of the simultaneous ascending auction design and the theory underpinning it, see Milgrom (1987, 1989), McMillan and McAfee (1987, 1996) and Wilson (1992).

In implementing this auction design, the fundamental issues for the SMA were:

- development of auction rules that were capable of sustaining a two dimensional auction;
- implementation of an auction management system; and
- selection of optimal market design in terms of the number of lots, and the shape of the lots.

The first spectrum licence auction was scheduled to take place in the 500 MHz bands, in spectrum that had been cleared in the later 1980s and then left unused. This band was selected as an ideal low-risk proving ground for the SMA's 'radical' new ideas.

Auction rules

The challenge with auction rules was to take the basic United States design and translate it into Australian 'legalese', consistent with the *Radiocommunications Act* 1992, and the wider Australian legal framework. To do this, the SMA contracted a retired head of the Office of Legislative Drafting to work directly with the SMT to craft the rules. Despite having this very experienced legal drafter, the translation of the auction design took nearly eight months.

Since the auction design was new to Australia, and the SMA was keen to avoid unnecessary risk, it commissioned Charles River Associates (CRA) in association with Market Design Incorporated (MDI) to review our rules. The brief to CRA/MDI asked for a review of the translation of the auction rules, some assessment of the SMA's market design proposals, advice about possible improvements and certification that the rules implemented a robust auction methodology. MDI has, as principals, noted auction design authorities such as Professor Paul Milgrom, Professor Bob Wilson, Professor John McMillan, Professor Preston McAfee and Professor Peter Cramton, all of whom were involved as advisers during the FCC auctions. CRA brought to the partnership Doctor David Salant who also advised during the FCC auctions.

Following a detailed and generally favourable report from CRA/MDI the SMA had a high degree of confidence in its auction design, provided that some minor modifications were implemented.

Having auction rules was one thing — being able to conduct an auction was another entirely.

Auction system

In late 1995, I travelled to the United States to attend a conference at Princeton University, which reviewed the FCC's experience with this form of auction. Part of that mission included meetings with FCC officials in Washington DC to explore implementation of an auction system, including gaining an understanding of the computing infrastructure necessary to support an auction and to source computer software.

Discussions to purchase software from the FCC never progressed beyond polite informal exchanges because the price tag that the FCC had put on its software, initially suggested to be around US$400 000, was considered to be far too high by a factor of about ten.

The SMA decided early in 1996 to develop its own software, using rapid application development (RAD) techniques. A budget of around $50 000 was felt to be feasible for all systems development, and provision was also made for fitting out a secure auction facility and fitting the facility out with the necessary computer infrastructure.

The total cost to the SMA for all of this activity was less than $140 000 and well within the overall budget provision for the development and implementation of the spectrum licence concept. It is interesting to note that this cost was fully recovered in the first *15 minutes* of bidding in the 500 MHz auction and was a fraction of the price originally suggested by the FCC for their software alone.

The SMA's software implemented a number of design enhancements compared with the FCC system, including map-based point-and-click functions to select areas for bidding and a number of error detection and warning routines.

Prior to deploying the auction system, Deloitte Touche Tohmatsu audited it end-to-end (twice). The SMA had a good deal of confidence in the system. In addition to the audits, the SMA conducted a live auction that ran for 15 rounds. The participants in the trial included all bidders registered in the 500 MHz auction plus an additional 15 industry, government and individual bidders who volunteered to assist in testing.

Market design

The last significant issue in the implementation of simultaneous ascending auctions for spectrum licences concerned the lots that should be offered for allocation. The issues were, for a three dimensional auction, how many areas and how many bandwidth divisions should be offered.

This points to a very real and practical dichotomy in auction design. On the one hand, theory would suggest that ultimate flexibility comes from offering a very large number of small and arbitrary allocation lots. Large numbers of small lots permits a wider set of permutations of bidder preferences to be satisfied and so should yield a more efficient outcome. On the other hand, large numbers of lots present an administrative problem for bidders that even the most sophisticated information systems support is unable to address. In theory at least, the SMA could have offered 21 998 STU area grid cells multiplied by 8 000 1 kHz bandwidth divisions: more than 175 million lots. The information systems necessary to allow bidders to bid on this number of lots from their own desktop would have been formidable. The problem for bidders in tracking 175 million lots also defies contemplation. At the other end of the scale, the SMA could have conducted an English auction, for one lot, covering the whole bandwidth, over all of Australia. The problem for bidders would be reduced, but that would not necessarily result in an efficient allocation. There could be only one 'winner'.

In all of the SMA's development of spectrum licensing, staying true to the theoretical ideal, while important as a goal, has always been tempered by pragmatism in implementation.

In early thinking, the SMA considered a large number of arbitrary areas, possibly as many as 50, and up to 50 bands, giving potentially 2 500 allocation lots. Advice from Professor John McMillan during a visit to the SMA, however, suggested that this might be too ambitious. No one had attempted to run an auction of this size. On the basis of Professor McMillan's advice, the SMA's proposals evolved into the final market design offered in the 500 MHz band auction: 17 areas and 54 bands. When some combinations of area and band were withdrawn from sale for technical reasons, the SMA was left with 838 allocation lots.

Each lot on offer was a collection of STUs. In the area dimension, 17 areas were created from the spectrum map grid of STU cells. The areas were defined by considering a population density model, the digital elevation model (RadDEM), existing radio sites and propagation models of typical transmitters operating from those sites. In other words, the SMA accepted the pragmatic need to undertake some judgement about practical market design, basing areas on real markets and practical spectrum use.

The SMA defined for the 500 MHz auction an STU bandwidth of 12.5 kHz. In the 4 MHz paired configuration (a total of 8 MHz) on offer in the 500 MHz auction, this provided for 640 separate STU bandwidths. The SMA aggregated these to assemble the 54 bandwidth parcels offered for sale. To promote both large and small users getting access to spectrum, lot bandwidths varied from

12.5 kHz (1 STU), 25kHz (2 adjacent STUs), 100 kHz (8 adjacent STUs), 500 MHz (40 adjacent STUs) and 1 MHz (80 adjacent STUs). Again, this reflected a degree of pragmatism. The prospect of offering bands at the STU resolution simply resulted in too many lots for practical management or understanding from our bidders.

500 MHz band spectrum licence auction

The 500 MHz band spectrum licence auction took place between 3 February and 25 March 1997. It concluded after 64 rounds and raised $1 062 077.32, including bid withdrawal penalties. There were 13 registered participants in the auction and all but one were successful in winning lots in one or more areas. The SMA issued ten year non-renewable licences with effect from 1 June 1997. The highest bid of $53 335.50 was made on a 1 MHz lot in Adelaide. On a population basis the highest bids were received in the Townsville area. Nelson (1997) provides a fuller analysis of the results of the 500 MHz auction.

In terms of the goals of spectrum licensing, the simultaneous ascending auction design has enabled the successful implementation of a technology transparent spectrum access right.

A notable feature of the results of the auction is the wide variety of different bandwidth configurations that were won by the successful applicants. It suggests strongly that the theoretical prediction that this form of auction facilitates efficient aggregation of lots to satisfy market preferences has been satisfied.

Feedback from the successful applicants indicates that potential service configurations are as varied as bunked mobile voice and data communications, fixed wireless modems for data and protection of wideband telecommunications systems. This variety could not be contemplated easily under the centrally planned approach to spectrum management. The ACA now suspects that some of the successful applicants purchased spectrum for investment purposes, or to establish licensing schemes in competition with the ACA's own licensing activities — again, consistent with the goals of reform.

A number of lots did not attract bids and were passed in at the auction. The ACA is considering, in the light of post-auction queries, conducting another smaller auction later this year to dispose of the unsold lots. Several licensees have also indicated that they regret not making larger 'eligibility payments' that would have allowed them to acquire more spectrum in the 500 MHz auction.

The auction has demonstrated that market mechanisms can be used successfully to allocate spectrum for competing uses and technologies. The success of the auction gave the SMA the confidence to recommend that spectrum licensing and spectrum auctions be the preferred mechanisms for allocating spectrum for new telecommunications services later this year.

11.5 The future of spectrum licensing in Australia

In order to meet the Government's objectives for a more open and competitive telecommunications market after 1 July 1997, the ACA is proposing to reallocate parts of the 1.8 GHz band and parts of the 800 MHz band by issuing spectrum licences. This spectrum is to be auctioned using the simultaneous multiple round auction in late 1997. This will provide additional capacity for new services, including new PCS, which in turn will lead to increased competition in the provision of mobile telephony.

The ACA considers that making a considerable amount of spectrum available in both the 1.8 GHz and 800 MHz bands will provide good opportunities for new telecommunications services to emerge, for existing carriers to expand, and for a range of technologies to be deployed.

The ACA has not yet released details of how the spectrum will be apportioned between lots of different bandwidth covering different areas. Nevertheless, it is likely that spectrum will be sold in about 20 areas, with up to 25 frequency band divisions. For a number of reasons, a number of these combinations will not be permitted and so the total number of lots is likely to be in the order of 220 to 250 allocation lots. This is an even simpler market design than that attempted in the 500 MHz auction.

The public will be given the opportunity to comment on a draft marketing plan before the procedures are finalised. Subject to government consideration, the ACA aims to publish final plans around September together with invitations to register for the auction.

The PCS auction is expected to generate wide industry interest. The spectrum auctions in the United States have been very successful in allocating licences efficiently, and have attracted interest from around the world. Allocation of this spectrum is expected to usher in new players leading to increased competition, which should increase service innovation and decrease prices.

11.6 Conclusion

Radiofrequency spectrum is an important national economic resource, which forms an input cost to virtually every sector of the Australian economy. It is important to our national well-being that this resource is used efficiently and effectively. Increasing demand for spectrum services, congestion in and competition for prime blocks of spectrum, the rapid pace of technological change and service innovation and recent structural reforms in telecommunications have placed the traditional administrative system of spectrum management under increasing pressure. To meet these challenges, the SMA implemented significant reforms in spectrum management. A major part of these reforms has been the selective introduction of a market system of spectrum management of which spectrum licensing is an integral component. The SMA successfully deployed the United States designed simultaneous ascending auction to allocate spectrum licences.

This auction design, unlike many others, allows market factors to determine the allocation of spectrum resources between users, and also allows preferred aggregations of spectrum to emerge in response to market conditions. This provides for market conditions to be a determinant of spectrum use.

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PLENARY SESSION 1

Comments and discussion

Frank Wolak (Stanford University)

One of the questions I was hoping you would expand upon is the endogenising of market structure in the sense of how that happens — do we go from having a single firm to multiple firms supplying this obligation? What happens in terms of the bids and things?

Paul Milgrom (Stanford University)

What happens in the auction is that the bids are made. The bids in this specific proposal we made are two part bids that express what your minimum subsidy requirement would be if you were the sole supplier in America and if you were one of two suppliers in America. If the cost penalty for having two suppliers in the market is sufficiently small, where we have criteria which are adjustable criteria for determining what is sufficiently small means, then the auction establishes that there are two suppliers in the market. If one of the suppliers in the market is the incumbent carrier that incumbent continues to provide service and the other winner has a transition period during which it is allowed to enter and begin providing service, at the end of which it has to be offering a service to anyone who requests it in the relevant area.

If the incumbent is not one of the winners there are alternative transition arrangements that are specified. You want to make sure, as in any procurement auction, before you finally accept the bids that the carrier is qualified to provide the service so there is a transition, there is a checking of qualifications that occurs. A lot of this is affected by Unites States law and regulatory policy. The 1996 *Telecommunications Act* specifies that any eligible telecommunications carrier can become a carrier of last resort and it says what that is.

The qualifications there specified are insufficient to be sure that they are actually able to provide the service, so we have been forced to structure the transition around the law to make sure that bidders who are supposed to be eligible to bid are allowed to bid, and yet to ensure that after the option is over those who are undertaking obligations are actually capable of fulfilling those obligations.

Joshua Gans (Melbourne Business School)

Every second microeconomic reform issue in Australia, the goal of which is to eliminate some form of cross subsidisation that might have occurred in a previously public owned industry or something like that, a lot of that had to do with coverage, as you mentioned here, but there are other stickier things that could be concerns. For instance, in telecommunications there is a debate about timed versus untimed local phone calls. Where in Australia the concern is about, in the year of deregulated competition, that sort of service, which is often argued and supported by social objectives for simplicity and other things, and concern about complexity and what have you, might be something that the government might wish to encourage a provider, maybe its own publicly-owned provider, to supply. Could we think of extending options for those sorts of subsidies, as well as cross subsidisation issues, or constraints on pricing that the government might want at least one operator to offer?

Paul Milgrom

There are some hard issues here that are not inherently auction issues. They are issues of determining values. Let me just draw a connection between some of the issues you were talking about in the universal service issue. In describing what constitutes the basic service that these guys are going to provide, there is a question about should we be charging for minutes of use. If simply providing access to the network is what is required and a relatively small number of minutes of use are included in the basic service definition, then competition from wireless carriers becomes a serious option in a lot of these areas. Typically one of the more expensive parts of wireless service is the charge for air time whereas typically that is not the case for wireline service. Depending on how those definitions are set you can encourage entry or not. In the context we have been looking at here, those are part of the decisions that the regulators are making.

Could we set those things by auction? Somebody has to be representing the public in determining where the values lie to the consumers here, and I think that is really the regulator’s role in specifying these basic service packages — deciding where the value lies, what exactly is it that we are trying to procure and what constitutes a satisfactory basic service offering. So I don’t think that auctions can be used to answer the question of what is most valuable for customers when we are talking about technologically imperfect substitutes where they can’t all be offered at the same time, and letting the customers must choose for themselves in the market.

Question

But it might be a way of pricing a regulatory auction. That is, if you have a political constraint for some other non-economic reason to do something that is what universal service obligation might be. It might be a way of working out or helping the process generating the cost benefit analysis at the time.

Paul Milgrom

Yes, I agree with that.

Question

The question in my mind is that I detect a similarity in the revelation principle you have here with the so-called Groves Clark / Clark Groves mechanism which is conventionally applied to the pricing of public goods. Am I correct or I am missing it?

Paul Milgrom

No, I passed over some slides of what I would call the Vickrey Groves mechanism because all three of those contributions were related. In fact, among the former slides that I passed over included a Vickrey Groves Clark implementation of this. So, yes, there is a close connection.

Question

So basically, in general you are saying that any mechanism that makes it in such a way that what you pay doesn't depend on what you reveal about yourself would work?

Paul Milgrom

No. You are asking the technical question— that has to do with dominant strategy implementation. The Vickrey Groves Clark analysis was not about that, it was about implementing something in particular, some outcome in particular. The revelation principle is a principle that says that if you find any mechanism that implements, using this notion of implementation, this Bass Nash equilibrium notion of implementation, any mechanism at all that implements any outcome at all, then there is a direct revelation mechanism that also implements that outcome.

Consequently, when you do your optimisation you don't have to search over all possible kinds of rules, you can search only over direct revelation rules. That makes it possible. This is Meyerson's big contribution. It makes it possible to formulate and solve the problem of what is the optimum mechanism. The set of all possible rules is way too big a set for us to write down and search over. But the set of revelation mechanisms is not too big a set and the fact that the best you can do with one of the revelation mechanisms is the best you can do with any mechanism makes it possible to write down mathematically and solve the problem of what is the optimal auction in this context.

Losantha Perera (Eastern Energy Ltd)

I want to make a clarification and then a question. The clarification is in terms of when you are dropping off subsidiary requirement, is it because that in the auction design process you re looking at it from the public benefit point of view and as such you expect that there is now a government-funded subsidiary going into the provision of that service, and that is where you are talking of a subsidiary requirement? Because there may be instances of auctions which does not require a public benefit coming in, or rather a government subsidy. For example, electricity companies were self funded and therefore didn't have something coming from the Government as such, and that's the whole situation.

In that sort of context when you talk of new benefits to the customers as part of the valuation model that you have, is it also meaning that because the auction bidders are able to think of new uses of that electricity, or whatever their business is, so therefore they can generate new production, give more new service to the customer, so that there is a benefit to the customer coming there? But does it also involve the customer relocating his resources to that particular substance that is being used?

For example, if you take a very stark example of a casino and where you can have the customer giving that resources to the casino which would otherwise have gone to may be buying the milk or something. Now, in that sort of situation would that be also brought into the model, or can you bring it into the model to say the depreciation of that resource going from one to the other would mean that there would be harm done to the public benefit? Is that a plausible thing to be taken up in your model?

Paul Milgrom

There were two questions. The first one was why there had to be subsidies at all in the context and the second one concerned the responses of where these benefits came from.

Regarding the first question, what is going on in the United States is, on account of the telephone deregulation, we are anticipating increased competition in providing a local telephone service. So we anticipate that in those areas where profits are relatively high and those areas where at what is specified to be the affordable price, let us say $15 a month is taken to be the affordable price, where the costs are significantly lower than that we expect those prices to be driven down by competition.

Right now the subsidies to the high cost areas are being provided for implicitly by profits earned in the low cost areas. The Government wishes to maintain service in the high cost areas. Somehow or other we are going to have to be paying for these extra costs that are incurred in the high cost areas. The question is where is that money going to come from? And the answer that provided by the *Telecommunications Act* is by explicit subsidies for firms that undertake these carrier of last resort obligations.

Where are these explicit subsidies going to come from? They are going to come from some kind of telecommunication surcharge and those surcharges are going to create costly distortions in the market. How are we going to keep those surcharges low? Who should the suppliers be? The auction is designed to allow us to answer those questions using a market-type mechanism without the need for extensive regulatory intervention. That is what is going on there.

In terms of the consumer benefits, I did not model the consumer benefits in any detail. I simply assumed for the purposes of the auction design that consumers benefit from competition. If there is a larger set of suppliers consumers get some benefit from that. I had in mind that if there are a larger set of suppliers, typically either there would be innovations or there would be more variety and service. If there is a wireline provider and also a wireless provider you may have more options as a customer to add mobility to your basic service or to add cable television offerings to your basic service. Generally, I have simply assumed in my benefits specification that the more competition or wider set of providers benefits consumers.

Could we take into account other sorts of affects of the kind you have described? Again, I have used a reduced form in modelling the benefits. You may disagree with me about what the nature of these benefits are and if you do you would reach different conclusions about the form of the optimal auction. But I have not tried to be explicit at all about substitution away from socially valued services into less valued services. I have taken as an input into this model consumer benefit function where consumers benefit from more variety and more competition and they benefit from lower costs and I have not done any more detailed analysis than that of consumer benefits.

Chris Pritchard (South Australian Office of Energy Policy)

This is a simple question. Essential services or essential use — is that catered for by reserving certain capacity before the auction or is it just a question of bidding high?

Ian Hayne (Australian Communications Authority)

We can do that. The preferred way of approaching it from a theoretical perspective would be to have the bid in an open auction and top them up from the public purse. But there are obviously some very sensitive political issues there and people in those sorts of utility industries tend not to think in those terms. They tend to see themselves as a public good and they therefore, or at least in their discussions with me, tend to say that we should be exempt from auctioning because we are a public good. From my point of view, I am interested in the spectre of efficiency, and these sorts of techniques can be used against the spectre of efficiency and I would argue that those emergency services especially need to up their act in terms of efficiency anyway. So, I don’t know.

It is a long way to go in that front and I think we will continue to use the traditional apparatus licensing approach for some time yet to deal with emergency services and those sorts of things. Ideally, their transitional property rights regime will give them much better certainty and much better flexibility to deploy that resource themselves. They have just got to have a bit of education.

Michael Cunningham (Queensland Treasury)

A slightly related question. You said that your objective was to put the spectrum into the hands of those who value it most — the same as the SEC’s objective. I believe that the Minister announced last night that in the telephone spectrum you will not be able to bid for the whole spectrum, but only a portion of it.

Ian Hayne

There are bidding caps imposed in the ...(indistinct)...

Michael Cunningham

What is the rationale for that?

Ian Hayne

They are quite competitive bidding caps. They reflect that the current industry is dominated by one former monopoly carrier and we are in transition through a regulated duopoly to a liberated market. That is the rationale.

Jerome Fahrer (Allen Consulting Group)

You said you only had a thin market for the 500 MHz auction. Could you tell us how many bidders you did have and, if you know, what does the experimental economics literature say about how many bidders you need for this kind of auction before you get something approaching an efficient outcome?

Ian Hayne

Part A — 13. Part B — I think I'd prefer to defer to Paul on that — that is, the literature's view of thin market problems.

Paul Milgrom

You are asking about experiments. They had 13 bidders, 12 of whom ended up winning some licences. The issue is, is that enough to be competitive? That also depends on how many licences were being sold. There were quite a large number of licences being sold here which means that probably it was in the interest of some bidders to withhold some demand to keep the prices lower, and that leads to less efficiency, theoretically. There aren't very many experimental auctions that have been of this size that — there is not relevant experimental evidence on the specific question that you asked.

Losantha Perera

What is the drive time of ...(indistinct)...

Ian Hayne

The 500 MHz was ten years fixed term non-renewable and the PCS spectrum auction will be 15 year fixed term non-renewable. At the end of 15 years we have another auction. My team gets to ride again.

PLENARY SESSION 2

Invited paper 12

Market power in electricity pools*

Frank Wolak
Stanford University

* Dr Wolak commented on changes in the Australian electricity industry by referring to principles discussed in a paper entitled 'The impact of market rules and market structure on the price determination process in the England and Wales electricity market'. This paper is available in PDF format on the internet at: ftp://zia.stanford.edu/pub/papers/eandw.pdf.

The abstract of the paper is reproduced hereafter for the reader's convenience.

The impact of market rules and market structure on the price determination process in the England and Wales electricity market

Frank Wolak (Stanford University) and
Robert Patrick (Rutgers University)

Abstract

In this paper, we argue that the market rules governing the operation of the England and Wales electricity market in combination with the structure of this market presents the two major generators — National Power and PowerGen — with opportunities to earn revenues substantially in excess of their costs of production for short periods of time. Generators competing to serve this market have two strategic weapons at their disposal:

- the price bid for each generation set; and
- the capacity of each generation set made available to supply the market each half-hour period during the day.

We argue that because of the rules governing the price determination process in this market, by the strategic use of capacity availability declarations, when conditions exogenous to the behaviour of the two major generators favour it, these two generators are able to obtain prices for their output substantially in excess of their marginal costs of generation. The paper establishes these points in the following manner. First, we provide a description of the market structure and rules governing the operation of the England and Wales electricity market, emphasising those aspects that are important to the success of the strategy we believe the two generators use to exercise market power. We then summarise the time series properties of the price of electricity emerging from this market structure and price-setting process. By analysing four fiscal years of actual market prices, quantities and generator bids into the market, we provide various pieces of evidence in favour of the strategic use of the market rules by the two major participants. The paper closes with a discussion of the lessons that the England and Wales experience can provide for the design of competitive power markets in the US, particularly California, and other countries.

PLENARY SESSION 2

Comments and discussion

Paul Milgrom (Stanford University) and Peter Hartley (Tasman Institute) intervened in this session. Unfortunately, the record of the comments and discussion is not of sufficient quality to reproduce here.

PLENARY SESSION 3

Invited paper 13

Markets for privately produced public goods

Graciela Chichilnisky*
Columbia University

* UNESCO Professor of Mathematics and Economics Director, Program on Information and Resources, Columbia University

13.1 The new global markets

Markets are a dominant institution in the global economy. As the century turns, however, the market itself is evolving. Two major trends are markets for knowledge and environmental markets. Markets for knowledge hold the key to the dynamics of the world economy: telecommunications and electronics, biotechnology and financial products, all involve trading products that use knowledge rather than resources as the most important input. Environmental markets are starting to emerge. The Chicago Board of Trade started trading emissions of sulphur dioxide (SO_2) following the Clean Air Act, and water markets are contemplated in California. The first global environmental market has been created: following our earlier proposal (Chichilnisky 1995, 1996) the 166 nations who are parties to the Framework Convention for Climate Change (FCCC) agreed in Kyoto, December 1997, to create an international framework to trade carbon emission credits among industrial nations.[1]

Markets for knowledge and environmental markets are different because they trade a different type of good, privately produced public goods (PPP goods), rather than the private goods that characterize traditional markets. With private goods — such as apples or machines — traders can choose what they wish to consume independently of each other. Knowledge and environmental goods are different: the planet's atmosphere is the same for all, and knowledge can be shared without losing it. As explained below, knowledge and environmental

[1] These are the so called Annex I countries, see Article 6, paragraphs 1 and 5 of the Kyoto Protocol. I advanced the proposal for the creation of an international framework for trading emissions permits at an international OECD conference in Paris, in 1993, and in 1994 at a workshop of "Joint Implementation and Beyond" organized under the auspices of the Global Environment Facility (GEF) with the participation of the members of Bureau of the International Negotiating Committee of the Framework Convention on Climate Change (FCCC) at Columbia Business School in May 1994. In December 1995 the proposal for the creation of an International Bank for Environmental Settlements (IBES) that would organize and regulate emissions trading was presented officially at a keynote address to the Annual Meetings of the World Bank, Washington D.C. and in various publications proposing blueprints for this trading regime, see Chichilnisky (1996a,b). In November 1997 The Rockefeller Foundation and the Global Environment Facility organized a workshop to discuss the creation of the IBES in Bellagio, Italy. In December 1997, Article 6 of the Kyoto Protocol, paragraphs 1 and 5, formalized the creation of such an international framework. The actual modalities, regulation and monitoring of the trading of emissions will be decided at the next Conference of the Parties (COP4) of the FCCC, to take place in Buenos Aires, November 1998. Columbia Earth Institute is organizing a follow up conference for the FCCC in April 1998.

assets are privately produced public goods, PPPs. Markets trading PPPs may be important in the future, because knowledge and environmental resources are key trends in the world economy, trends that lead the transformation that I call the knowledge revolution.

Focusing on these new markets, I analyze here the introduction of new institutions and the policies that can lead the transformation of industrial society into a sustainable society through the knowledge revolution. I focus on a new type of economic organization, involving markets that trade a mixture of private and public goods. These new markets require new regimes of property rights, also proposed here, and carry with them the seed of a society which encourages the creation of knowledge, and could lead to a better use and distribution of knowledge and of the world's natural resources.

13.2 Ecology and the knowledge revolution

Today the world faces a major challenge: to find practical paths for sustainable development. This means finding ways to reorient consumption patterns and use of natural resources in ways that improves the quality of human life, while living within the carrying capacity of supporting ecosystems.[2] This requires building a future in which humans live in harmony with nature. We are far from this goal, indeed in many ways the world economy is moving in the opposite direction.

However, just as the environmental problems generated by industrial society are becoming a threat to human welfare, industrial society is in the process of transforming itself. The rapid pace of this change has led me to call it a revolution. The change is centered in the use of knowledge and for this reason I call it the "knowledge revolution". What characterizes this so-called knowledge revolution?

The question is best answered in a historical context, by contrasting the current situation with the agricultural and the industrial revolutions, two landmarks in social evolution. Neither of the two previous revolutions is complete. Across the world we find today pre-agricultural societies populated by nomadic hunters and gatherers, and most of the developing world is still within agrarian societies. While the two previous revolutions are still working their way

[2] This is the definition of sustainability adopted by the Bruntland Report, and is anchored in the concept of development based on the satisfaction of "basic needs", a concept that was introduced and developed empirically in Chichilnisky, 1997a and b. Sustainable development is explored also in Caring for the Earth, a joint publication of IUCN, UNEP and WWF.

through human societies, knowledge is becoming a leading indicator of change. Knowledge means the ability to choose wisely what to produce, and how to do it. This ability is becoming the most important input of production, and the most important determinant of wealth and economic progress. It resides mostly in human brains rather than in physical entities such as machines or land. It is worth pointing out that the important input is *knowledge* rather than information. This is the difference between the computer industry, which is based on information technology, and other sectors such as telecommunication, biotechnology and financial sectors, which involve knowledge. The value of biodiversity resides on its knowledge content, according to ecologists such as E. Wilson and T. Lovejoy. *In an nutshell: knowledge is the content, information is the medium.*

The content (knowledge) is driving change, and this is facilitated by the medium (information). Information technology is the *fuel* for knowledge. Its abundance and inexpensive supply fuels the growth of sectors such as communications, biotechnology and global finance. Information technology fuels knowledge sectors because it performs the important role of allowing the human brain to expand its limits in the production, organization and communication of knowledge. The most important input of production today is not information technology itself: it is knowledge.

13.3 Characterizing the knowledge revolution

We may characterize the knowledge revolution as a period of rapid transition at the end of which *knowledge* itself becomes the most important input of production, the most important factor of economic progress and wealth. For example, today the knowledge content of biodiversity for improving public health and human welfare, is identified as a crucial source of economic value. By contrast, in prior revolutions the most important inputs were land (in the agricultural revolution) and machines (in the industrial revolution), that became better utilized because of new knowledge. Knowledge differs fundamentally from land and machines in that it is not rival in consumption. More on this below.

The process of change that I call the knowledge revolution is underway. Some indications include the fact that the value of corporations in the stock exchanges of the world is increasingly measured from their knowledge assets, such as discoveries, patents, brand names and innovative products, rather than from their capital base or physical assets. This means that knowledge-type assets (such as patents) are increasingly regarded as the most important source of economic progress in the corporation, and of its value. At the level of the economy as a whole, knowledge of mathematics and sciences has become a good predictor of national economic progress across the world, see table 1 and figure 3 below.[3] In this period of change the USA leads the pack. Today more Americans make semiconductors than construction machinery. The telecommunications industry in North America (USA and Canada) employs more people than the auto and the auto parts industries combined. The US health and medical industry alone have become larger than defence, and also larger than oil refining, aircraft, autos, auto parts, logging, steel and shipping put together. More Americans work in biotechnology than in the entire machine tools industry. Most US jobs in the last twenty years were generated in smaller, knowledge intensive firms driven by risk capital. In the US, one third of the nation's growth is accounted for by the knowledge sectors, see figure below,[4] so that knowledge is an increasingly important determinant of economic progress. The knowledge sectors of the US economy already grow much faster than the rest of the economy, and therefore account for most of the dynamics of economic growth, see figure 4 below.[5]

Knowledge sectors consume less resources and have less ecological impact than the rest; thus they could decrease environmental damage once they become dominant in the economy. The question is whether the pace and scope of this process of change will foster a sustainable society in a timescale that matters. Encouraging and accelerating this transition is key. The economic transformation depends among other things on the evolution of the new markets for knowledge and for environmental assets. These require special analysis since, as already mentioned, knowledge and environmental assets are privately produced public goods, leading to new types of markets with new challenges and new opportunities for action.

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3 Data from TIMSS: Third Mathematical and Science Study, American Federation of Teachers, American Department of Education.

4 See also *Business Week*, "The New Economy: What it really means" by Stephen Shepard, Editor-in-Chief, November 17, 1997, p. 40, last paragraph.

5 This is despite the fact that current systems of accounting undervalue the contribution of electronics, which are extraordinarily productive and offer rapidly lowering costs for their products, so their weighting factor in GDP (market prices) decreases with time. In a nutshell: in the US knowledge products are rapidly becoming the most important input of production, source of value and economic progress. Similar statistics hold in most of the OECD nations. Development of knowledge sectors is slower in Europe than in the US because their financial markets and property rights systems are not so flexible and well developed and regulated. This is discussed further below.

13.4 A service economy?

It is important to differentiate the knowledge revolution from a service economy which used to be thought to be the latest stage of the industrial society. A service economy is characterized by the production of services more than goods, and it is similar to a knowledge economy in that knowledge sectors often involve services (such as finance). It is true that services now make up the largest part of advanced industrial economies. However the analogy ends there. The inevitable concern about the service economy is that it could lead mostly to service-oriented labor, such as the labor employed in the food services or in bank processing, requiring little skill and achieving lower wages. The radical difference between the service economy and the knowledge society is that in the latter the typical worker is highly skilled and generally well paid. Furthermore the worker's knowledge resides in her/himself and her/his brain and life experience, rather than in the machines that complement labor. Therefore the knowledge economy could result, with proper institutions, in a society that is more human oriented than the industrial or the service society.

13.5 Knowledge as a privately produced public good

As *knowledge itself* becomes the most important input to production, economic behaviour changes because knowledge is a rather special type of good. It is called a *public good* by economists, not because it is produced by governments but because it is not "rival" in consumption. This means that we can share knowledge without losing it. This is a *physical* property of knowledge, not an economic property, and as such it is quite independent from the organization of society. Nevertheless the economic rules governing the use knowledge — for example whether patents can be used to restrict its use — can have a major impact on human welfare and organization. More on this below.

Knowledge is also different from conventional public goods of the type that economists have studied for many years, such as law and order or defence, which are supplied by governments, in a centralized fashion.[6] What is unique about knowledge among other public goods is that, although it is a public good at the level of consumption, it is supplied by *private* individuals who are its creators. At the level of production, therefore knowledge is like any other private good: costly to produce, and the resources used to produce knowledge

[6] Classic work in the area of public goods by Lindahl, Bowen and Samuelson, as well as modern work on the subject, analyze public goods in the context of a government policy rather than in the context of competitive markets.

often cannot be used for other purposes. Producing knowledge requires economic incentives similar to those for producing any other private good.

13.6 A vision of the knowledge society

A distinct possibility is that in the next century a new society will develop, a society that is centered in human creativity and diversity, and which uses information technology rather than fossil fuels to power economic growth. The vision is a human-centered society which is deeply innovative in terms of knowledge and at the same time very conservative in the use of natural resources. The patterns of consumption and resource may not be as voracious as those in the industrial society, and may be better distributed across each society and across the globe. The knowledge society may achieve economic progress that is harmonious with nature.

This vision is only a possibility at present. Without developing the right institutions and incentives this possibility may never come to pass, and a historical opportunity may be lost; we need institutions to bridge the gap between a grim present and a bright and positive future. The rest of this paper will address this issue, for which an economic analysis of knowledge is required.

13.7 The paradox of knowledge

To produce new knowledge creators need economic incentives. This could involve restricting the use of the knowledge by others: patents on new discoveries work in this fashion: by restricting others' use of knowledge. This creates a problem because any restriction in the sharing of knowledge is inefficient, since knowledge could be shared at no cost and by doing so it can make others better off. So restrictions on the use of knowledge are inefficient after knowledge is created. However, without some restrictions there may be no incentive to create *new* knowledge. I call this the paradox of knowledge. This paradox is at the heart of the success of the knowledge society, of its ability to bring human development for many and not only wealth for a few.

13.8 New property rights regimes

New property rights regimes are needed to deal simultaneously with the need to share the use of knowledge for efficiency, while at the same time preserving private incentives for production. The appendix contains a technical summary of how this would work in practice within competitive markets.

I propose substituting patents by a system of *compulsory licences* which are allocated in a specific way that ensures optimal use of knowledge in society, and which are then traded, in a *competitive* fashion, along with all other goods in the economy. In this new scheme, the right to use knowledge is unrestricted and by law everyone has access to it; however users must pay the creator each time they use this knowledge. Since the licences are traded in competitive markets, they ensure that the creators of knowledge are compensated for their labor in a way that reflects the demand for their products and therefore their usefulness for society. Prices are uniform and determined by competitive markets. Since licences are compulsory, they make knowledge available to all. In this sense this regime differs fundamentally from patents because, in principle, patents can restrict the use of knowledge.[7] No restriction in the use of knowledge is allowed in the system I propose. However a key issue is the distribution, use and applicability of the licences, to which we now turn.

It is clear that a system of licences on knowledge products (e.g. operating systems for software, biological information, how-to-do-it systems) could preserve or even worsen today's uneven distribution of wealth in the economy. This is because the knowledge economy has a built-in incentive for the creation of monopolies. Indeed, any knowledge based corporation is a "natural monopoly" a technical term used to indicate that the cost of duplicating knowledge products (such as software products) is very small, and therefore the larger the firm the lower are its costs. This is an extreme case of "increasing returns to scale" where larger firms have an advantage over their competitors, and therefore can prevent entry by newer and smaller competitors. Such natural monopolies are characteristic of the knowledge society. How to avoid their effects in concentrating welfare in the hands of very few?

The system of property rights proposed here takes into account these possibilities. It establishes how the distribution of licences is a crucial element in achieving efficient solutions. It shows that markets with knowledge operate differently than the standard markets, because knowledge is a public good that is privately produced. The solution is to achieve a distribution of property rights on licences that is negatively correlated with the property rights on private goods, and beyond this to ensure that markets for knowledge act competitively.

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7 Patents *can* be negotiated, but they do not *have* to be. Owners of patents are legally entitled not to negotiate them, effectively creating a "monopoly" during the period of the patent's life. Compulsory licences do not have this feature.

The results in Appendix I make this proposal rigorous within a standard model of a market economy.

How can such a system of property rights become accepted? This concern parallels that proceeding the introduction of laws to ensure fair trade, a matter on which natural monopolies have offered and continue to offer much resistance and which is eventually overcome by society as a whole.

In reality there are substantial economic incentives for corporations to accept fair trading and the systems of property rights that we propose, although it is clear that more economic thinking and business education is needed before the acceptance becomes widespread. For example, even those producers that benefit in principle from increasing returns to scale could support a system of licences in which the lower income segments of the population are given proportionately more rights to use knowledge than the rest. Consider as an example the case of worker training schemes, school subsidies, etc. Because knowledge is so important for the productivity of society as a whole, and produces positive “externalities” on all producers, there is an incentive to develop a skilled pool of workers. Corporations know that skilled workers are essential to the success of knowledge industries.

All this is formally established in a proposition presented in the appendix, establishing that for an efficient market solution, one that cannot be improved so as to make everyone better off, lower income traders (individuals or in the case of international trade, nations) should be assigned a larger endowment of property rights in the use of knowledge.

In practice, this means a larger amount of licences to use knowledge are assigned to such lower income countries or groups. The scheme I propose is new but realistic. In fact, similar systems are already in place in most industrial societies within the educational system. Examples are school subsidies, that offer subsidized access to education to lower income groups. Another example is the auctioning of use of airwaves by the US Federal Government: in Washington D.C. minorities and women are given substantial discounts when they participate in auctions for the purchasing of property rights on the airwaves. In certain cases this involves a 40% discount of the auction prices.

13.9 Licences: we make it, we take it back

The system of property rights proposed here, while unique in its economic formulation, is reminiscent to a development that is already taking place in the US corporate world, a development that is also connected with environmental issues that have a public good aspect: the disposal of materials involved in heavy industrial products, such as vehicles and electronic equipment. Leasing vehicles and electronic equipment is now a thriving business that hardly existed twenty years ago. One of the largest packaging companies in the world, Sonoco Products Co., started taking its used products off customers' hands after its CEO Charles Coker made a pledge in 1990: “we make it, we take it back.” The policy has already been adopted by the car industry in Germany, where car manufacturers are responsible for disposing of the vehicles that the customers return at the end of their useful life, due to environmental concerns. Another example arises in the floor covering industry. Ray Anderson, CEO of Atlanta-based corporation Interface, the largest maker of commercial carpeting, has set up as a goal to create zero waste while making a healthy profit, and takes back the used products that it sells to recycle them. The mission of their businesses, all these business people say, is to sell *services,* not products. In other words: rather than selling TVs, selling viewing services; rather than selling vehicles, selling transportation services, rather than selling carpets, selling the comfort and visual services that carpets provide. Licencing has the advantage that the producers have an incentive to minimize waste and environmental damage — for example, the waste produced by wrapping or by defunct car bodies — as they will be responsible for it. These business people see licencing services as the way to the future, particularly when consumers are confronted with paying for the disposal of industrial waste.

Implicit in this a new system of property rights is an idea that we share: *licencing the use of services* rather than *owning the products that deliver those services*. The products in the corporate examples just described share another common characteristic with our economic approach: they have some of the characteristics of public goods in that they produce negative environmental “externalities”. Knowledge, as we saw, also produces externalities, although positive.

Knowledge, as we saw above, has much in common with environmental assets: it is a privately produced public good. Knowledge products have been licenced for many years, although this has been done in a case-by-case manner, without securing the competitiveness of the market for licences, and without securing the distribution of property rights that would ensure efficient outcomes. In this sense, the new developments in industry reported here move in the same direction as the system of property rights, involving licences, proposed in Appendix I and discussed above. *These new systems of property rights that I propose can be thought of as an improvement, an institutionalization and an economic formalization of licencing and leasing systems that have recently emerged in advanced industrial economies*

13.10 Human impacts of property rights on knowledge

The rules that govern the use of knowledge in society are all important because they can lead to threats and opportunities for human development, both directly and through the possible changes in the patterns of consumption of goods and services. They can determine the impact of human societies on the environment and on resource use, as well as determine inequalities across the world economy. The way we use and distribute knowledge casts a very long shadow on human societies. How does this occur?

A historical comparison helps to explain this process. In agricultural societies the way humans regulated the ownership of land, which was then the most important input to production, led to social systems such as feudalism. Ownership of land had therefore a major impact on human welfare and on economic progress. Similarly in industrial societies the way humans organize the use of capital, which is its most important input of production, leads to very different social systems such as socialism and capitalism. Indeed, these two systems are defined by the rules on ownership of capital. In socialism ownership is in the hand of the governments or other public institutions, and in capitalistic systems capital is in private hands. Property rights on capital have mattered a great deal, and have even led to global strife in most of this century.

Since capital is the most important input of production in industrial society, it is clear that property rights on capital had an enormous impact on the organization of society, on economic progress and on peoples' welfare. Similarly in the knowledge society the way humans organize the use of knowledge, which is the most important input to production, will determine human welfare and economic progress across the world. This means that human institutions that regulate the use of knowledge, such as property rights and markets for knowledge, will become increasingly important. However as we saw knowledge is a different type of commodity than land or capital: it is a public good. Markets with public goods, and other economic institutions such as property rights on public goods, are still open to definition and require much economic analysis. Markets themselves will operate differently in the knowledge economy, because of the nature of the goods traded is different. There will be new challenges and new opportunities.

13.11 The ecological impact of knowledge-intensive vs. resource-intensive growth

In order to focus the analysis it is useful to distinguish two patterns of economic growth, two extreme cases of which is a spectrum of possibilities: economic development that is *knowledge-intensive,* and that which is *resource-intensive*. The former simply means achieving more human welfare with less material input. The latter means achieving more production by means of more material use. These two categories were introduced in Chichilnisky (1995a, 1994b).

There are excellent historical examples of the two patterns of development, and of the differences they induce on economic growth. East Asian nations fit the knowledge intensive paradigm, while Latin American countries and those in Africa, fit well the pattern or resource-intensive growth. On the whole knowledge intensive development strategies succeeded, while resource intensive development patterns lost ground. Chichilnisky (1997) studies the historical patterns focusing on East Asian nations that are now called the Asian Tigers, including Japan, Korea and Taiwan, and later those called the Small Tigers, such as Singapore, Philippines, Hong Kong and Malaysia. These focused on exports of technology-intensive products such as consumer electronics and technologically advanced vehicles, and overturned the traditional economic theory of "comparative advantages". In contrast with East Asian nations, Latin America and Africa followed a resource intensive pattern of development and lost ground.

13.12 Difference scenarios of development in the North and the South

The most dynamic sectors in the world economy today are not resource-intensive; they are, rather, knowledge-intensive, such as software and hardware, biotechnology, communications and financial markets (Chichilnisky 1994b, 1995a). These sectors are relatively friendly to the environment. They use fewer resources and emit relatively little CO_2 Figure 8 shows this for the US economy. Knowledge sectors are the high-growth sectors in most industrialized countries.

Some of the most dynamic developing countries are making a swift transition from traditional societies to knowledge-intensive societies. Mexico produces computer chips, India is rapidly becoming a large exporter of software, and Barbados has recently unveiled a plan to become an information society within a generation, (Fidler 1995). These policies are an extension of the strategies adopted earlier by the Asian Tigers, Hong Kong, Republic of Korea, Singapore, and Taiwan (Province of China), who have achieved extraordinarily successful performance over the last twenty years by relying not on resource exports but rather on knowledge intensive products such as consumer electronics. By contrast, Africa and Latin America emphasized resource exports and lost ground (Chichilnisky 1994b, 1995a, 1995-1996).

The lessons of history are clear: not to rely on resource exports as the foundation of economic development. Africa and Latin America must update their economic focus. Indeed, the whole world must shift away from resource-intensive economic processes and products. In so doing, fewer minerals and other environmental resources will be extracted, and their price will rise. This is as it should be because today's low resource prices are a symptom of overproduction and inevitably lead to overconsumption.

Not surprisingly, from an environmental perspective one arrives at exactly the same answer: higher resource prices are needed to curtail consumption.

Producers will sell less, but at higher prices. This is not to say that all will gain in the process. If the world's demand for petroleum drops, most petroleum producers will lose unless they have diversified into other products that involve fewer resources and higher value. Most international oil companies are investigating this strategy. Indeed British Petroleum and Shell are already following such policies.

The main point is that nations do not develop on the basis of resource exports, and at the end of the day development can make all better off. As the trend is inevitable, the sooner one makes the transition to the Knowledge Revolution, the better.

The data and a conceptual understanding of how markets operate leads to the same conclusion. Economic development cannot mean, as in the industrial society, doing more with more. It means achieving more progress with fewer resources.

13.13 People centered development: opportunities and threats

The knowledge revolution could develop in different ways, depending on the way our institutions and policies unfold. As already explained, knowledge has the capacity of amplifying current discrepancies in wealth, because knowledge sectors can lead to natural monopolies such as those that arise due to the adoption of operating systems[8] or other standards. In the North-South context, knowledge sectors could amplify the differences in wealth between the North and the South. If this occurs, then the low resource prices from developing countries will persist, since they are caused in part by the necessity to survive at low income levels within a difficult international market climate. It has been shown that with current institutions of property rights, anything that leads to

[8] Microsoft *Windows* operating system is a case in point.

more poverty will lead to increased resource exports from developing countries, (Chichilnisky 1994a).

On the other hand, knowledge sectors will flourish in those nations that have skilled labor. Several developing nations are, or could be soon, in that position. For example, the Caribbean and Southeast Asia are a case in point, as are many areas in Latin America, (Harris 1994).

The main issues here are

- to abandon the resource intensive development patterns that these nations have followed for the last fifty years, with the support and encouragement of the Bretton Woods institutions such as the World Bank and the IMF, and
- to seek to establish the institutions (property rights, financial structures) that could lead them to overcome the “comparative advantages” mirage and thus avoid the heavy stages of industrialization, moving directly to the knowledge society.

Heavy accumulation of capital (financial or physical) is not needed for most knowledge sectors. What is needed is highly skilled labor, of the type that does not require expensive machinery or heavy capital investment in plants, and good managerial ability, all knowledge inputs that rely on a pool of abundant skilled labor. A good example is Bangalore’s software industry.

Appendix I

Markets with knowledge

This section presents a general equilibrium model of a market with knowledge.[9] As explained above, knowledge is a privately produced public good. In this sense the model presented below is a model of a market that trades private goods as well as a privately produced public good, in this case, knowledge.

A general equilibrium model with knowledge

There are two traders, North and South, denoted by the index i=1,2 respectively, each producing two goods: one private good (x) and another a privately produced public good (a) representing *knowledge*. Each trader h has finite resources (24 hours a day) which are allocated to produce either private goods or knowledge. For each trader i=1,2 there is a trade-off between producing more private goods and producing more knowledge. However, more knowledge leads to higher productivity. Formally for i=1,2:

$x_i = g_i(a_i, a)$, with $g_i \; / \; a_i \rangle 0$, and $g_i \; / \; a \rangle 0$

where

$$a = \sum_{i=1,2} a_i \,, \text{ or } a = \sup_{i=1,2}(a_i)$$

Each trader or region has property rights $\Omega_i \in R^2$ on private goods and own licences that allow them to use knowledge, $\overline{a_i} \in R^2$. Traders derive utility from the use of private goods x,

$$u_i(x_i),$$

Through compulsory negotiable licences, knowledge is available to *all*. Traders may use their licences to access knowledge or may sell their licences in the market. If they wish to use more knowledge than their licences allow, they buy more licences in the market.

Markets for licences are competitive: everyone pays the same price for the same licence; prices are determined by equating supply and demand, and no trader can influence market prices.

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[9] The OECD model is called GREEN.

Market equilibrium with knowledge

The equilibrium of the market is defined as follows. It consists of

- A price π*, the relative price between private goods and licences to use knowledge,
- For each trader i = 1, 2 a level of initial allocation of property rights on licences to use knowledge in the economy $\overline{a_1}, \overline{a_2}$,
- For each trader i a level of consumption of private goods x,
- For each trader i knowledge production a_i^*,

so that:

- Each trader i allocates time optimally between the production of knowledge and the production of private goods,
- Each trader maximizes welfare within a budget defined by prices and property rights:

$$Max\, u_i(x_i)$$
$$s.t.\ x_i = g_i(a_i^*, a^*) + {}^*(\overline{a_i} - a_i^*)$$

  i.e. the value of consumption equals the value of production plus the value of licences bought or sold, and

- Markets clear

$$\overline{a_1} + \overline{a_2} = a_1^* + a_2^*$$

A competitive equilibrium determines endogenously a number of prices and quantities:

- the initial allocation of property rights on knowledge in each trader or region;
- the level of production and of consumption of private goods and of knowledge by each trader or region,
- the level of trade of private and knowledge between the parties, as well as
- the terms of trade between the private good and knowledge, *, which is the market price of the licences.

The price * can be thought of as a market determined licence fee on using knowledge, since it is a monetary value that must be paid for using knowledge above the level allowed by the initial allocation of property rights.

Equity and efficiency in markets for knowledge

The most attractive feature of competitive markets is the efficiency with which they allocate resources, requiring minimal intervention once an appropriate legal infrastructure is in place. This was Adam Smith's vision of the "invisible hand," and was formalized in the neoclassical theory of competitive markets that has prevailed in the Anglo-Saxon world since the 1950's. The efficiency of markets is summarized in *the first welfare theorem of economics*. This theorem establishes that the prices and the allocation of goods and services that arises in a competitive market equilibrium are efficient, in the sense that there is no other allocation that can make everyone better off. The first welfare theorem has practical importance. It had a major impact in the functioning of economies such as the US, which are market oriented. It underlies much of its *anti-trust legislation*, as well as its *insider trading laws*, the laws that restrict *price discrimination*, and other forms of *market discrimination* including gender and age discrimination. The rationale is simple and compelling. Since, according to this theorem, competitive markets ensure an efficient allocation for society, it follows that competitive markets are a "public service." Economic actions that undermine the ability of the market to act competitively therefore detract from the public good.

The first welfare theorem is no longer valid in markets in which in addition to traditional goods (private goods such as apples or machinery) one trader's public goods, such as the rights to use the planet's atmosphere, or knowledge. There is however a new first welfare theorem, reported below as the *first welfare theorem for privately produced public goods*, that establishes that the market reaches efficiency, but only for certain allocations of the rights to use knowledge, or licences. The results are quite general, and apply to any competitive market in which, in addition to private goods, trading involves privately produced public goods. Therefore they apply to environmental markets as well as markets with knowledge. In the case of environmental markets, in the special case considered in those works, the licences involved permits for the use of the atmosphere of the planet as a sink for the emission of greenhouse gases.

Theorem 1

(Chichilnisky, Heal and Starrett). Given a total global level of emissions $\bar{a}$, there exist a finite number of ways to allocate property rights on emissions among the two regions, i.e. there is a finite way of distributing emissions rights (or permits to emit) $a_1, \overline{a_2}$, with $\sum_{i=1}^{2} \overline{a_i} = \bar{a}$, so that at the resulting competitive equilibrium, the allocation of resources in the world economy, a_1, a_2, x_1, x_2, is

Pareto efficient. For distributions of permits other than these, the competitive market equilibrium is inefficient. When both traders have the same preferences, then the region with more private goods should be given fewer property rights on the public good.[10]

This theorem is illustrated in figure 9, provided below. The figure shows a starting distribution of permits that gives proportionately more rights to emit to the North, and computes the corresponding competitive market equilibrium allocation. In a second step, by redistributing the permits in favour of the South and at the same time tightening the emission targets on the whole world, the competitive market achieves a new equilibrium allocation which increases the welfare of the North and the South. This means that the first distribution was not Pareto efficient, and illustrates the potential efficiency gains obtained by redistributing permits in favour of the poorer countries.

Theorem 2

By allowing world emissions $\bar{a}$ to vary, one obtains a one-dimensional manifold of property rights from which the competitive market with permits trading achieves a Pareto efficient allocation of the world's resources. For allocations of property rights different from these, the competitive market does not achieve Pareto efficient solutions.

Proof

See Chichilnisky (1996f and 1997c).

The following result applies to the model presented above, which is different from the model of environmental markets in that the privately produced public good is *knowledge*. The mode with knowledge is different from the model of emission markets, because knowledge does not enter in the utility function (as the environmental asset does), but does enter into the production function to improve productivity (as the environmental asset does not).

[10] For environmental markets rather than markets with knowledge see also Chichilnisky 1993a, Chichilnisky and Heal 1994 and Chichilnisky, Heal and Starrett 1993.

Theorem 3

First welfare theorem of economics for markets with knowledge. There exists a one-dimensional manifold of property rights allocations from where the market with knowledge achieves an efficient allocation of resources. For allocations of property rights other than these, the competitive market does not achieve Pareto efficient equilibria.

Proof.

See Chichilnisky (Chichilnisky 1996f) and (Chichilnisky 1997c)

Theorems 2 and 3 identify the set of all “efficient” allocations of property rights on the use of knowledge, i.e. all allocations of licences to use the available knowledge products in society from which the competitive market achieves efficient allocations of resources as in the case of private goods. It turns out that the allocations that yield efficient solutions provide more property rights to those traders who have fewer property of private goods. As an example, this would involve providing those on a low income free access to a number of software programs, a number that is larger than for someone with a larger income.

The intuition behind these results is simple. Competitive markets in which public goods are traded have more stringent criteria for efficiency than markets for private goods. In addition to the standard marginal conditions (i.e. marginal rates of substitution must equal the marginal rates of transformation) the allocations must also satisfy the Lindahl-Bowen-Samuelson conditions for efficient levels of the public good, requiring that the sum of the marginal rates of substitution equals the (common) marginal rate of transformation between the private and the public good. Since more conditions are needed, the standard competitive allocations are not generally “first best”, i.e. they are not generally Pareto efficient. In addition it can be shown that they are not “second best” efficient as well, where second best means that they are Pareto efficient conditional on a total level of world emissions which does not exceed the given target. Generally the total amount of the public good is lower in competitive markets than the “first best” or Pareto efficient level.

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PLENARY SESSION 3

Comments and discussion

Paul Milgrom (Stanford University)

I was wondering about second welfare terms. When you talk about efficiency, I know that in the paper that you described by you and Geoff and Dave Starrett at Stanford, the thing that was great or better about the different levels of emissions than the fixed levels we were comparing to something that involved a kind of change. It was still a constrained deficiency within the level of emissions there on the result correctly, which leads me to wonder about second welfare terms here, whether the things that you are considering are all competitive equilibria, whether all efficient outcomes are competitive equilibria, or whether there are things that we are looking at are efficient that are not competitive equilibria.

Graciela Chichilnisky (Columbia University)

Very good question. In fact, you recall that the theorem I put today is different than the theorem with Geoff Healey and David Starrett in the sense that the money for the ...(indistinct)... locations, you only mention I suppose to finesse the point. That was oriented to you, to that question that you have asked me before. Why? Because in my theorem the quantity is now left floating. So you say, please consider people can produce and they can produce more and they can produce less and the question is it may be true that once you let a quantity flow then you will always get efficiency. But the answer is no, you still need a one dimensional manifest. So that also ...(indistinct)... to answer that question.

But your question now is more sharp. You are saying, the second welfare theorem tells me you can access every efficient location through a market solution. Is this still true? It is not true within the context of the theorem with David Starrett, for the obvious reason that you just mentioned. But it is true in the context of a more general theorem that I proposed, because in that theorem the quantity is left floating and just choose the quantity ...(indistinct)... frontier. You can realise that with an appropriate ...(indistinct)... What you do have, however, is covenants.

Remember I used the word covenants with property rights? What happens there is that these boundary conditions without which an equilibrium would not exist.

If you agree that does not exist but greater efficient locations do you will buy the second welfare theorem. But if their constraints are so destroyed then, I call them covenants although they could be something else, then leaving the total quantity floating, which I do in my theorem, would allow you to produce second welfare term. So I have qualified, yes, but it is my no means the same as second welfare term.

Peter Hartley (Tasman Institute)

Taking off with your parallel with the vouchers for education, the traditional way of thinking of that is that the low income people they wouldn't be purchasing enough education so there's positive externality associated with more education, but the high income people would buy enough any way, so the externalities are infra-marginal. So that would be one way of thinking about why you might want to subsidise the low income people to have education, if for them the externality is marginal, but for the high income people it is infra-marginal. Does that intuition carry over to what you are talking about as to why the distribution and efficiency might be linked in your model, the same kind of idea that it is only for the low income people in the sense that the externality is marginal?

Graciela Chichilnisky

...(indistinct)...

Peter Hartley

I think it is related because what I am saying is the standard way of thinking about the subsidy below income people is the high income people would buy enough education any way, so even though the minimal amount of education has a positive externality, the externality is infra-marginal for the higher income people, but it is still marginal for the low income people. So it is in the interest for the high income people to subsidise the low income people because they are not consuming enough education. There is still a positive marginal externality. So that would link in the income distribution element that there is a reason for subsidising the people with low amounts of private goods just because for them the externality is still marginal but for the high income people it is not.

Graciela Chichilnisky

...(indistinct)...

The remaining discussion is indistinct...

CONFERENCE PROGRAM

Thursday 10 July 1997

8.30 am	**Registration**
9.15 am	**Introduction and welcome**
	Robert Kerr (Industry Commission)
9.30 am	**Plenary session 1**
	Paul Milgrom (Stanford University)
	Ian Hayne (Australian Communications Authority)
11.00 am	**Morning tea**
11.30 am	**Panel session 1: Telecommunications following deregulation**
	Henry Ergas (Auckland University)
	Graeme Woodbridge (Australian Competition and Consumer Commission)
	Philippa Dee (Industry Commission)
1.00 pm	**Lunch**
2.00 pm	**Plenary session 2**
	Frank Wolak (Stanford University)
3.00 pm	**Afternoon tea**
3.15 pm	**Contributed papers sessions**
	John Logan (Australian National University) Contracting out under incomplete information: auctioning incentive contracts without transfers
	Stephen King (Australian National University) Regulation by negotiation: a strategic analysis of Australia's essential facility access regulation

Partha Gangopadhyay (University of Western Sydney)
Should access price be regulated in a vertically integrated industry?

Stephen Nelson (University of Adelaide)
An analysis of Australia's 500 MHz auction

Rob Fraser (University of Western Australia)
Modifying the RPI-X regulatory system to include profit sharing

Harry Bloch (Curtin University)
Pricing in Australian manufacturing: an analysis of panel data

Robert Smith (Energy Australia)
Best guessing — industry forecasting behaviour: evidence from the Australian housing industry

Charles Hyde (University of Melbourne)
An empirical analysis of the causes and consequences of mergers in the Australian petroleum industry

RJ Brooker and GH King (Victorian Treasury)
Open all hours: the economic consequences of deregulated shopping hours

Mita Bhattacharya (Monash University)
The structure-conduct-performance relationships and simultaneity: evidence from Australian manufacturing

7.00 pm **Conference dinner**
Raymond Priestly Room, Student Union Building, University of Melbourne

Friday 11 July 1997

8.30 am **Contributed papers sessions**

Billy Jack (Australian National University)
Competition in the health insurance market

Kathy Kang (New South Wales Treasury)
The forces shaping Australia's electricity market

	Terry A'Hearn (Environment Protection Authority) Environment protection and harnessing market forces in Victoria
	Dick Damania (Flinders University) Financial structure and the effectiveness of pollution control in an oligopolistic industry
9.30 am	**Panel session 2: The national electricity market**
	Donald Anderson (Queensland Electricity Reform Unit)
	John Salerian (Industry Commission)
	Joshua Gans (Melbourne Business School)
10.45 am	**Morning tea**
11.15 am	**Plenary session 3**
	Graciela Chichilnisky (Columbia University)
12.15 am	**Lunch**
1.30 pm	**Panel session 3: Environmental regulation**
	Don Gunasekera (Industry Commission)
	Robin Stewardson (BHP Pty Ltd)
	Tim Fisher (Australian Conservation Foundation)
	Contributed papers session
	Natalia Nunes and Stephen Farago (Industry Commission) Economic impact of international airline alliances
	Tim Hazeldine (Auckland University) The costs of making competitive markets in New Zealand
	Ann Hodgkinson (University of Wollongong) Globalisation and networking — are they something new?
2.45 pm	**Afternoon tea**
3.00 pm	**Contributed papers**
	Henry Ergas (Auckland University) Are the ACCC's merger guidelines too strict? A critical review of the Industry Commission's Information Paper on market regulation

Stephen Ziss (University of Sydney)
Divisionalisation, franchising and strategic managerial incentives in oligopoly under uncertainty

David Prentice (La Trobe University)
Unpopular privatisation as a vote winner

Vivek Chaudhri (University of Melbourne)
Competition in the newspaper industry

Robin Stonecash (Bond University)
Competition policy and community services

Peter Forsyth (Monash University)
Determining the sale price of privatised natural monopolies

Ilias Mastoris (Industry Commission)
A quantitative analysis of anti-dumping in Australia

Gary Madden (Curtin University)
Market structure and productivity in Asia-Pacific telecommunications

Peter Dixon (Monash University)
A general equilibrium explanation of the rapid growth in Australia’s trade

Alexis Hardin and Tony Warren (Industry Commission)
International telecommunications reform in Australia

5.15 pm **Conference close**

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