39th Annual Conference of the Australian Agricultural Economics Society
University of Western Australia, February 14-16 1995

PRICE EQUALISATION IN THE RICE INDUSTRY AND THE DEVELOPMENT OF A SPATIAL EQUILIBRIUM MODEL

Randall Jones*, Carolynne James* and Gordon MacAulay**

Abstract

Previous studies have identified a number of economic implications associated with rice marketing arrangements, particularly price equalisation and cost and revenue pooling. The objective of this paper is to present a theoretical model of the NSW rice industry which indicates the areas of possible social gains and losses resulting from price equalisation. A description is given of a spatial equilibrium model of the rice industry which is being developed to estimate the extent of any social gains or losses.

The views expressed in the paper are those of the authors and do not necessarily reflect policies of NSW Agriculture or the NSW Government.

The preparation of this paper has benefited from helpful comments by Jim Booth, Scott Davenport, Roley Piggott and Gary Griffith.

* Economic Services Unit, NSW Agriculture Orange.
** Department of Agricultural Economics, University of Sydney.

1. Introduction

1.1 Background

NSW is currently the only Australian rice producing state. Estimated production for 1994 was 1,082,175 tonnes of paddy[1] rice, at an estimated gross value to growers of $240 million (Rice Marketing Board for the State of New South Wales 1994). Exports account for approximately 85 per cent of production with the remainder disposed of on the domestic market. Domestic rice use[2] averages 100,000 tonnes[3] per annum in recent years, 30,000 of which is made up of imports.

The NSW rice industry is geographically concentrated in the irrigation areas and districts of the Murrumbidgee and Murray Valleys located in southern NSW. In 1994 there were 2,603 rice growers who harvested 132,195 hectares at an average yield of 8.19 tonnes per hectare (Rice Marketing Board for the State of New South Wales 1994). NSW predominantly produces *japonica* varieties of rice. The varietal breakdown of production in 1994 was 764,101 tonnes of *japonica*, 280,880 tonnes of *indica* and 37,194 tonnes of fragrant varieties.

The marketing of rice produced in NSW is regulated under the Marketing of Primary Products Act (1983). The NSW Rice Marketing Board (RMB) was established in 1928 under the previous Marketing of Primary Products Act. Rice not voluntarily delivered to the Ricegrowers Cooperative Limited (RCL) within 7 days of harvest is vested[4] in the RMB and must be delivered to the RCL (pursuant to an agreement between RCL and RMB). To exercise those vesting powers granted by the State legislation the RMB is exempt under the Marketing of Primary Products Act (1983) from the Commonwealth Trade Practices Act (1974), which would normally prohibit control over the marketing of rice under anti-competitive conditions.

As a result of perceived duplication of duties, in 1985 the functions of the RMB and the RCL were merged. The RMB is no longer involved in the day to day marketing of paddy rice and vesting of the NSW crop appears to be the major remaining function of the Board. The RMB, apart from the Board Secretary, has no staff of its own with the four grower elected members of the Board also being members of RCL.

An important component of the 1985 merger was the appointment of RCL to be the sole agent of the RMB. Consequently, RCL carries out all rice milling and marketing functions and controls the wholesale marketing of milled rice on both the domestic and export markets.

The resulting institutional arrangement in the rice industry allows RCL to equalise returns between the domestic and export markets, pool revenues across markets, time and quality, and pool the costs of receival, storage, milling and marketing across individual growers.

During 1994 the rice industry requested from the Minister for Agriculture and Fisheries an extension to the vesting powers of the RMB. The rice industry request was based on a number of reasons. First, there had been a significant expansion of rice production in NSW in recent years which had presented the industry with a challenge to provide sufficient infrastructure to cope with expanded production involving a large capital investment program funded from

---

[1] Harvested rice is called paddy. Through the milling process, after removal of the husk it becomes 'brown rice', and once the brown layer is removed the product becomes 'white rice'.
[2] Excludes stock changes.
[3] Milled rice. The conversion from paddy to a milled product results in a 30 to 35 per cent weight reduction.
[4] The effect of the vesting power is that upon the crop coming into existence it becomes the property of the RMB.

borrowings. The industry believed that only with the continuation of vesting, whereby there is surety of total crop delivery, would lenders have confidence in the rice industry's repa; ..ent capacity.

Second, the rice industry believed that the issues of vesting and single desk selling were inextricably linked. The industry is strongly of the opinion that maintenance of the single desk exporter status of the RCL has allowed the rice industry to extract price premiums from particular export markets by having a greater degree of market power. The industry argues that maintenance of single desk negotiation is fundamental to success in securing access to the Japanese rice market.

The NSW Government in December 1994 agreed to a 3 year extension of the vesting powers of the RMB, from 31 January 1996 to 31 January 1999. A condition of the extension was that a review of the RMB, based on net public benefit, would be undertaken.

Any such review would have to weigh up potential social costs which result from the current marketing arrangements (such as price equalisation and pooling of costs and revenues) against any benefits which may result from single desk selling. This paper outlines a methodology by which an estimate may be made of the social costs associated with price equalisation.

1.2 Previous studies

The Industries Assistance Commission (IAC) originally estimated a transfer from consumers to producers, the 'producer transfer', of $9.8 million in 1986-87 (Industries Assistance Commission 1987). The Industry Commission (1990) revised the approach for measuring the effective rate of assistance of the rice industry after discussions with the industry. The producer transfer for 1988-89 was estimated at $6 million and the effective rate of assistance was calculated to be 11 per cent. The effective rate of assistance for total agriculture was 8 per cent for the same period.

The producer transfer is determined by multiplying the difference between domestic and export prices by domestic sales. The use of export parity as the appropriate benchmark indicates the maximum amount of assistance available to the industry from the marketing arrangements. The rice industry, however, questioned the existence of any producer transfer claiming that in a deregulated environment domestic prices would be maintained at levels closer to import parity due to the local advantages associated with domestically produced rice.

The producer transfer estimated by the Industry Commission is simply a measure of revenue flows from sectors of the economy. It is not a measure of economic surplus or the costs of resource misallocation and consequently may be an underestimate of the actual welfare impacts of the marketing arrangements.

As part of the NSW Government's review of statutory marketing, the rationale of the RMB and the appropriate form for future government regulation in the rice industry was assessed (Kraft, Piggott and Wright 1991). The principal recommendation arising from this report was to discontinue the vesting of the NSW rice crop and abolish the RMB.

Kraft, Piggott and Wright identified areas of social losses, in particular the area of 'waste' from resource misallocation, associated with rice marketing arrangements but were unable to quantify the actual values. The Minister for Agriculture and Rural Affairs in announcing the results of the review acknowledged the potential costs of the existing marketing arrangements but stated that he was not convinced of the extent to which the costs accrued. The Minister stated that he was aware of the significant benefits the arrangements brought the industry and, consequently, decided in May 1991 that the operations of the RMB would continue.

1.3 Study objective

The objective of this paper is to identify the economic implications associated with price equalisation in the rice industry. The framework presented by Parish (1962) is applied to this problem to identify changes in producer and consumer surplus' and other social welfare effects. An empirical framework is presented, spatial equilibrium modelling, which can be applied to problems involving price equalisation. It is demonstrated that such an approach can quantitatively assist the determination of welfare changes due to specific marketing arrangements. With further research, the developed model will provide a tool for measuring the actual costs associated with price equalisation and thus provide quantitative information on these issues to any forthcoming review of the rice industry.

2. Rice Market Structure

2.1 Market characteristics

The international rice market is volatile and competitive. Price volatility of the world market is attributable to supply variations, trade restrictions and product differentiation (Cramer, Wailes and Shui 1993). The majority of rice production is consumed in the country of origin. The level of surplus available after home consumption forms world trade supply.

Variations in harvests can cause the world market supply to fluctuate dramatically and promote fierce competition in periods of shortages. Government intervention in domestic markets is widespread in rice staple countries because of self sufficiency policies. These controls are reflected in the world market. International rice prices also vary considerably because rice types are not homogeneous or considered substitutable. *Japonica* and *indica* are the main traded rice varieties. *Japonica* is preferred by north Asian countries (Japan, China and South Korea) and *indica* is preferred in south Asia (Indonesia, Thailand and India).

The world rice market is relatively small compared to world production. In 1993 only 3.5 per cent of world rice production was traded (United States Department Of Agriculture 1994). The main competitors in the world market are Thailand, the United States, China and Pakistan. Australia has a mere 4 per cent share of world trade. It can be expected that under these circumstances Australia has little influence on international prices and world demand is therefore interpreted as perfectly elastic.

Traditionally there have been three sources of rice supply available to the domestic market: NSW RCL, Queensland produced rice and imported rice. Queensland rice production has currently ceased.

RCL has approximately 85 per cent of domestic market share and as it is the only domestic supplier on the market, has the potential to act as a domestic monopolist. This means it is possible for RCL to price domestic rice at levels higher than export parity[5] in order to maximise returns to the industry. As there are no restrictions on imports of rice into Australia it is conceivable that RCL would act more as a precautionary monopolist and not set domestic prices above import parity so as to minimise the extent of any potential import substitution.

[5] In a competitive market environment domestic rice would be priced closer to export parity.

2.2 Price equalisation and discrimination

Parish (1962) developed a framework for describing spatial price equalisation with a product sold in two separable markets. Using the dairy industry as an example Parish demonstrated that price discrimination involved transfer payments from taxpayers and consumers to dairy farmers. Moreover, the distortion of prices caused by the protective devices results in a misallocation of producers' and consumers' expenditures and consequent losses in real income.

Three conditions are necessary for price discrimination to successfully take place (George and Shorey 1978). There must be market power, it must be possible to sell the commodity to two or more groups of markets with different elasticities of demand, and it must not be possible to buy the product in the lower priced market and resell in the higher priced market. Generally the gains from price equalisation will be small unless elasticities differ significantly in the separate markets and a relatively large proportion of total output is sold on the higher priced market (Tomek and Robinson 1981).

The general Parish model considers the case of a homogenous commodity which is sold on a regulated domestic market and a single export market. The export demand facing the industry is assumed to be perfectly elastic, with the export price considerably lower than domestic prices. The domestic demand is assumed to be sheltered from import competition through some form of government intervention such as tariffs or quarantine restrictions. Hence the statutory marketing authority sets domestic price in the absence of import competition.

Longworth (1966) applied the Parish framework to the stabilisation scheme of the Australian wheat industry which had been in operation since 1948. Longworth demonstrated that the welfare effects of the stabilisation scheme differed depending on whether world market prices were higher or lower than domestic price. The introduction of a home consumption price and equalisation of returns in the Australian wheat industry, while achieving a reduction in the variability of both price and output, was determined to not only alter the free market welfare distribution but also changed the allocation of resources in the economy.

The principal assumptions adopted in the Parish and Longworth frameworks are used in this study of the rice industry. These are:

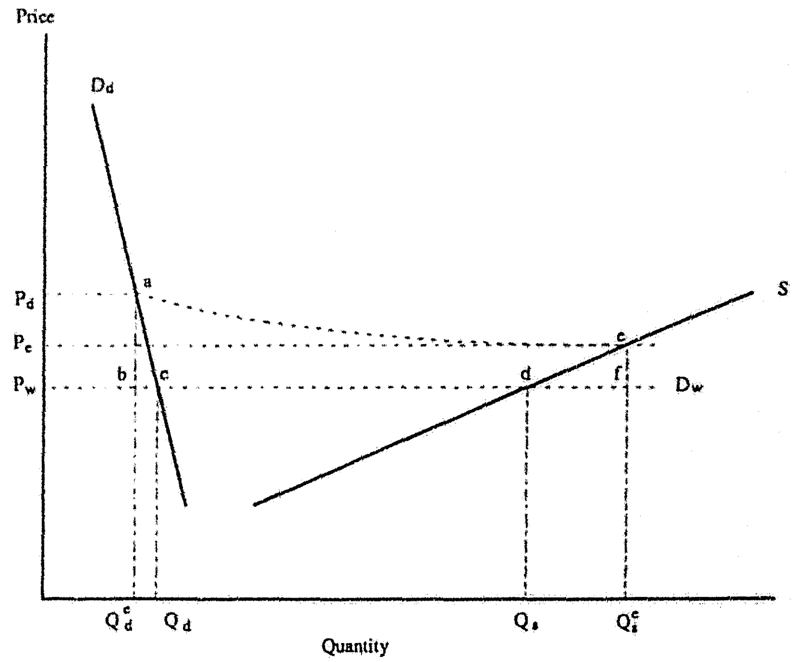
- rice growers aim to maximise profits;
- all decisions are made under perfect knowledge;
- the export demand curve for Australian rice is perfectly elastic;
- the domestic demand curve for rice has some negative elasticity over the relevant price range; and
- the long run domestic supply curve has some positive elasticity over the relevant price ranges.

It should be noted that it is possible to relax some of these assumptions during the course of any analysis.

In the standard Parish monopolist framework, where restrictions on imports exist, a statutory marketing authority can price a commodity above import parity in order to maximise industry returns. In the case of the rice industry, however, there are no trade restrictions on the imports of rice into Australia. Consequently, it is possible that RCL operates as a precautionary monopolist, as outlined in the previous section, instead of a monopolist in the standard Parish framework.

The effects of price equalisation under these circumstances are illustrated in Figure 1. Domestic pricing practices are represented by the setting of domestic price, P_d, above the ruling world price, P_w, which is set by the perfectly elastic world demand curve D_w. Domestic demand is represented by the demand schedule D_d and domestic supply by S. Under perfectly competitive conditions domestic price is equal to P_w, rice production is Q_s with Q_d consumed domestically and Q_s - Q_d exported. With discriminatory pricing the domestic price is set at P_d, with the locus *ae* representing the average return per unit of rice output (ie. the equalised price) from the domestic and export markets. At point *e* the average return curve intersects the supply curve resulting in the overall equalised price P_e and the corresponding total output of Q^e_s.

Figure 1: Price equalisation versus free market conditions



The effect of the price equalisation scheme is to increase output from Q_s to Q^e_s, increase price growers receive from P_w to P_e and reduce domestic demand from Q_d to Q^e_d. There are a number of distributional effects associated with this scheme. There is a gain in producer surplus represented by the area P_wP_eed. Due to the higher domestic prices there is a loss in domestic consumer surplus represented by the area P_wP_dac. In addition there is a social loss area, described as the resource misallocation cost of equalisation (Godden 1978), of *def* associated with the disposal of Q^e_s - Q_s of production at price P_w on the world market which is less than the marginal cost of production represented by the supply curve *S*.

3. The Standard Spatial Equilibrium Model

The spatial equilibrium model is a partial equilibrium approach and is generally solved by quadratic programming (Takayama and Judge 1964). Two alternative specifications of the spatial equilibrium model, the quantity and price formulations, were presented by Takayama and Judge (1971). The approach adopted in this study is the quantity formulation.

In a partial equilibrium analysis the view of the problem is restricted to a particular sector of the economy, in this example the rice industry, with all other factors held constant. The disadvantage of this approach is that it suppresses the interaction between commodities that are linked by substitution and competition. There are, however, a number of advantages of the partial equilibrium approach (Houck 1986). For specific policy schemes and interventions it provides clear results that highlight important differences among policy measures. It is extremely useful for assessing the direct and immediate economic impacts of policy intervention such as tariffs, quotas and export subsidies targeted at specific commodities. In general, partial equilibrium does not purport to completely represent reality. The purpose of this approach is to see as clearly as possible how individual trade policy decisions influence the market environment.

The graphical presentation of the spatial equilibrium problem involves the use of back to back trade diagrams. The standard spatial equilibrium model and corresponding price and quantity equilibria are illustrated in Figure 2. Linear supply and demand functions are shown as S_i and D_i and the excess supply and demand functions as ED_i and ES_i for region i. The equilibrium prices prior to trade taking place are $\bar{P}_1$ and $\bar{P}_2$. The equilibrium prices after trade takes place are P_1 and P_2. Per unit transfer costs from region 1 to region 2 are indicated by t_{12}. Pre-trade volumes supplied are represented by $\bar{x}_i$ and volumes demanded by $\bar{y}_i$. The direction of trade will be from the lower priced region to the higher priced region, so long as the price difference between the two regions is greater than the transfer cost of the goods. In Figure 2, trade from region 1 to region 2 is indicated by x_{12} and is equal to $x_1 - y_1$ or $y_2 - x_2$ in the two region case.

The effect of trade in Figure 2 is, for region 1, an increase in production from $\bar{x}_1$ to x_1 and price from $\bar{P}_1$ to P_1. Local demand declines from $\bar{y}_1$ to y_1 owing to the higher domestic price. In region 2 the extra supply of the good from region 1 leads to a fall in price from $\bar{P}_2$ to P_2. Demand increases from $\bar{y}_2$ to y_2 while local production declines from $\bar{x}_2$ to x_2.

The objective function of a mathematical programming model of the spatial equilibrium problem is quadratic. Takayama and Judge (1971) termed the objective as quasi welfare, which is defined in terms of the net social payoff and is measured as the area under the excess supply or demand curve. An alternative objective function to the quasi welfare is the net social revenue model as illustrated in Figure 3 (MacAulay, Batterham and Fisher 1988). If the vertical difference between the excess supply and demand curves is plotted against quantity traded, as shown in the middle part of Figure 3, then the result is a curve known as the demand for transfer services. This curve is downward sloping since it relates the quantity of goods that would be shipped at any level of difference in prices between the two regions up to the point where no trade would take place or the direction of trade would be reversed. The gross revenue to be gained by arbitragers at every level of trade (bottom part of Figure 3) is derived by multiplying the price difference by the level of trade and is quadratic in form. The net social revenue is derived by subtracting the total transportation costs. An important feature of this model is the assumption that arbitragers bid away any profits to be made in transferring the goods so that at equilibrium the net social revenue is zero.

Generally a primal-dual form is used for the spatial equilibrium model. This simply means that to form the primal-dual objective function the dual objective function is subtracted from the primal and the constraints from both the primal and dual are used. Properly specified this ensures the value of the objective function will be zero at the optimum.

Let i,j denote the regions which compose the discrete but divisible production and consumption locations. Transport costs per unit are expressed as

$t_{ij} \geq 0$, for all i and j.

The typical linear demand function will be represented is:

(1) $p_i = \lambda_i - \omega_i y_i$, for all i,

where p_i is the demand price in the ith region, y_i is the quantity demanded in the ith region and $\lambda_i > 0$ and $\omega_i > 0$.

The typical linear supply function is:

(2) $p^i = \nu_i + \eta_i x_i$, for all i,

where p^i is the supply price in the ith region, x_i is the quantity supplied in the ith region and $\eta_i > 0$.

These functions can be more compactly expressed in matrix form as

(3) $P_y = \lambda - \Omega y$

(4) $P_x = \nu + Hx$

For each region it is assumed that the quantity actually consumed, y_i, is less than or equal to the quantity shipped into the region from all supply regions,

(5) $$y_i \leq \sum_{j=1}^{n} x_{ji}$$

where $x_{ji} \geq 0$ is the quantity shipped from the jth to the ith region.

The actual supply quantity, x_i, is assumed to be greater than or equal to the effective supply from region i to all regions

(6) $$x_i \geq \sum_{j=1}^{n} x_{ij}$$

where $x_{ij} \geq 0$. The objective is to develop a mathematical programming model which will yield a competitive spatial equilibrium and allocation solution. The resulting model is to maximise

(7) $$Z = \lambda' y - v' x - y' \Omega y - x' H x - T' X$$

Figure 2: Representation of spatial equilibrium model with transfer costs

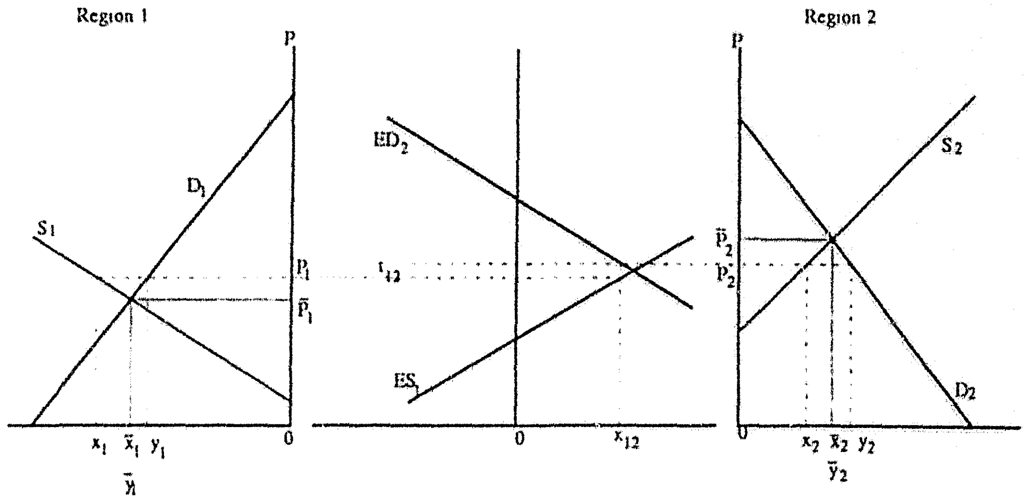
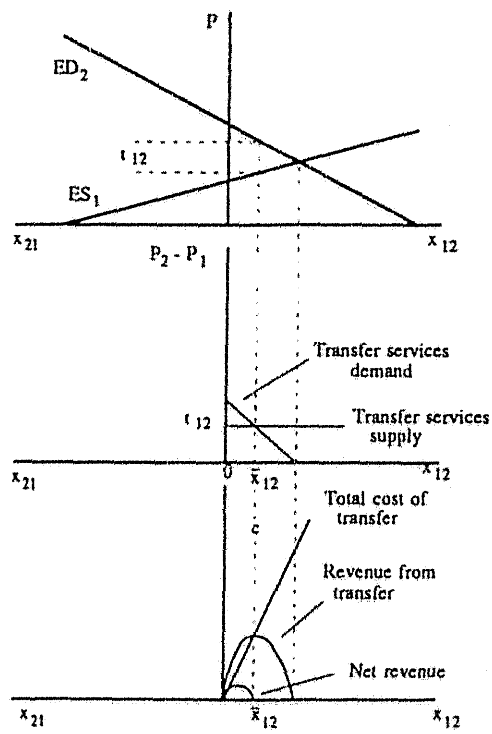


Figure 3: Representation of the net social revenue solution



subject to

$$(8)\quad \begin{bmatrix} \lambda \\ -\nu \\ -T \\ 0 \\ 0 \end{bmatrix} - \begin{bmatrix} -I & & -\Omega & & \\ & I & & -\mathrm{H} & \\ G_y' & G_x' & & & \\ & & I & & -G_y \\ & & & -I & -G_x \end{bmatrix} \begin{bmatrix} \rho_y \\ \rho_x \\ y \\ x \\ X \end{bmatrix} \leq 0$$

and

$$(y' x' X' \rho_y' \rho_x') \geq 0,$$

where

$$\lambda = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \lambda_n \end{bmatrix}, \quad \nu = \begin{bmatrix} \nu_1 \\ \nu_2 \\ \vdots \\ \nu_n \end{bmatrix}, \quad T = \begin{bmatrix} t_{11} \\ t_{12} \\ \vdots \\ t_{nn} \end{bmatrix},$$

$$\Omega = \begin{bmatrix} \omega_1 & & & \\ & \omega_2 & & \\ & & \ddots & \\ & & & \omega_n \end{bmatrix}, \quad \mathrm{H} = \begin{bmatrix} \eta_1 & & & \\ & \eta_2 & & \\ & & \ddots & \\ & & & \eta_n \end{bmatrix},$$

$$G_y = \begin{bmatrix} 1 & & & 1 & & & & 1 & & \\ & 1 & & & 1 & & & & 1 & \\ & & \ddots & & & \ddots & \cdots & & & \ddots \\ & & 1 & & & 1 & & & & 1 \end{bmatrix},$$

$$G_x = \begin{bmatrix} -1 & -1 & \cdots & -1 & & & & & & & \\ & & & & -1 & -1 \cdots & -1 & & & & \\ & & & & & & & \ddots & & & \\ & & & & & & & & -1 & -1 & \cdots & -1 \end{bmatrix},$$

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}, \quad x = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}, \quad X = \begin{bmatrix} x_{11} \\ x_{12} \\ \vdots \\ x_{nn} \end{bmatrix}.$$

4. Demand and Supply Functions

To specify a spatial equilibrium model of the rice industry, demand and supply functions are required to be estimated. Demand and supply functions have been estimated for processed white rice. The domestic supply function has been adapted from a paddy supply function to a processed white rice equivalent through the incorporation of a processing margin and a conversion factor.

4.1 Estimation of domestic and world demand functions

4.1.1 Domestic demand

Australian rice demand studies at retail and farm level are limited. In the domestic market the consumption of rice is relatively unresponsive to price (Quilkey 1974). International studies have attached relatively elastic values to Australian domestic demand based on stock elasticity estimates (Gardiner, Ronigen and Liu 1989). Elasticity estimates and demand functions used in world market studies, however, were generalised and not specific to the Australian market. Preliminary domestic demand functions were therefore estimated for this study. An extended analysis of the domestic retail and derived demand function for Australian rice is suggested for further research.

The RCL vertically integrates the milling, wholesale and retail stages of production. Consequently, interim prices between processing stages are not available. Information on marketing margins is limited due to commercial confidentiality, hence a demand function is derived for processed rice from retail price information rather than the estimation of a paddy equivalent domestic demand function.

Australian Bureau of Statistics data provided the majority of domestic demand statistics (Australian Bureau of Statistics). Annual data from 1970 to 1992 was used in domestic demand analysis. Over the last two decades Australian rice consumption increased in total and per capita despite rises in real prices. This suggested other characteristics influenced consumer rice purchasing behaviour. Explanatory variables examined included population growth, proportion of Asian population, price of substitutes and consumption expenditure combined with price and quantity information.

Changes in population composition, particularly increases in Asian population, considerably influenced consumption patterns. An expenditure variable on food consumption rather than an income variable was used to avoid bias[6]. Econometric studies of the relationship between rice and its substitutes and complements are limited. Survey studies suggest that increased substitution between rice and other staples is related to changes in dietary and eating patterns and convenience attributes rather than price differentials (Lewis 1994). Annual potato prices were included reflecting a real price increase over the last 20 years[7]. A meat price index was created from retail prices of beef, lamb, pork and chicken (Australian Bureau of Agricultural and Resource Economics 1993). Lagged variables were also incorporated and all values were deflated by the consumer price index. To estimate a bulk processed value for rice retail values were deflated by 50 per cent, this margin was based on comparisons of rice imports prices against retail prices.

---

[6] As a staple food item rice consumption is less dependant on income changes than luxury food items. Incorporating income changes instead of food expenditure can bias all items as luxuries.

[7] Pasta and vegetable prices were not used as seasonal variation meant that annual statistics were a poor representation of price movements.

Various functional forms, including OLS and log regressions, were estimated over 23 annual observations. Examination of coefficients from the resulting equations suggested that price, population growth, proportional change in Asian population and per capita consumption expenditure were key variables in domestic demand response (Table 1). Lagged variables were not a significant influence on results. Autocorrelation and partial autocorrelation tests (Box Jenkins procedures) were conducted and satisfied.

Linear equation 1 was chosen as the preferred general form of the domestic demand, primarily due its reasonable R^2 value and simplicity in collapsing to a linear function (Table 1). When collapsed into slope and intercept form the following function is derived:

$$p = 2212.53 - 0.0178y$$

Table 1: Demand function estimates

	Equation 1 Linear	Equation 2 Log linear	Equation 3 Log	Equation 4 Lagged
Constant	-276610	-.130066-E7	-12.6196	-322730
	(-4.51050)	(-11.1634)	(-9.38028)	(-4.69008)
Price	-56.1603	-30860.8	-.507947	-27.4937
	(-4.82714)	(-5.27466)	(-7.49624)	(-1.60797)
YPC	7.87408	68004.2	3.93364	7.66520
	(2.87738)	(2.90551)	(4.07951)	(2.87245)
OVSBSH	13660.0	306030	1.61515	15888.4
	(3.47440)	(3.67570)	(5.95850)	(3.77543)
Lagged Price				-23.8055
				(-1.80405)
R^2	0.930	0.925	0.966	0.947
Adj R^2	0.919	0.913	0.960	0.935
SER	6899.57	7183.63	0.83197	6206.99

where:
Price is real rice price in $A/tonne
YPC is per capita private food consumption expenditure
OVBSH is percentage of overseas born within total population
Lagged price is real price lagged one year
SER is standard error of regression

Note: Values in brackets represent *t* values

4.1.2 World demand

The perfectly elastic 'world' demand function was derived from international prices. The Thai white rice indicator price was used to represent world market prices, which averaged US$295 in 1993-94 (United States Department of Agriculture 1994). This converts to AUS$395 at a US/AUS exchange rate of $0.75.

The resulting function for world demand is:

$$p = 395$$

4.2 Estimation of domestic supply function

In the absence of available data to conduct an econometric investigation regional linear programming models were used to estimate the supply function for domestic rice. The models used represented the major rice producing areas of NSW: the Murrumbidgee Irrigation Areas, the Murrumbidgee Irrigation Districts, Coleambally Irrigation Area and the Murray Irrigation Districts. The models are deterministic, assuming risk neutrality, which can be expected to lead to some overestimation of supply response (Kingwell 1994).

An advantage of using a programming model approach to estimate rice supply is that possible supply curve shifters, such as changes in adoption of technology and water policy (water prices, allocation and transferable water entitlements) can be taken into account.

The models are short term in nature and the specification included various soil types, irrigation technologies, environmental restrictions on rice areas, water allocation limits, supply system constraints, and labour availability. Crop rotations involved various sequences of rice, wheat and sub-clover. Other activities included lucerne, hay making, livestock, labour hire, crop selling and various season feed pool transfers. More details of the technical coefficients contained in the models can be found in Jones (1991), Wall, Marshall, Jones and Darvall (1994) and Curthoys, Marshall and Jones (1994).

The price of rice was varied parametrically in the models to provide derived supply data for each region. The supply data for paddy rice was converted to a processed white rice supply function by adding a processing margin of 60 per cent (United States Department of Agriculture 1994) and conversion factor of 70 per cent (Kraft, Piggott and Wright 1991; United States Department of Agriculture 1994) from paddy to milled product, ie a weight reduction of 30 per cent.

To reduce complexity, it was assumed that adjustment and conversion of milled retail values to paddy values was constant. The processing margin of 60 per cent is expressed in terms of output quantities thereby accommodating the quantity conversion factor. The assumption of fixed proportions implies that paddy is combined with all other inputs used in converting paddy to bulk rice at a constant per unit processing cost. It is acknowledged that real rice processing margins are more likely to be variable because of economies of scale, however, this is not an assumption which influences the fundamental results derived (Kraft, Piggott and Wright 1991). This assumption, along with other abstractions made in deriving farm demand from the retail demand, require further development[8].

The revised data was aggregated and a linear regression applied. The resulting processed rice supply function was obtained:

$p = 45.61 + 0.00028x$.

[8] Further examination of derived demand relationships is required but has not been developed for this paper. For more information see Wohlgenant and Haidacher (1991).

5. Alternative Spatial Equilibrium Model Specifications

Statutory authorities can price discriminate on the domestic market and equalise returns to producers in one of two ways. First, they can physically limit the disposal of a commodity by setting a domestic quota, which consequently leads to an increase in domestic price. Second, they can truly price discriminate by setting a higher price on the domestic market, leading to some reduction in quantity demanded by domestic consumers, the magnitude depending upon the price elasticity of demand. The specification of the spatial equilibrium model will be dependant upon the manner in which the statutory authority operates.

In the first case, a quota restriction is introduced into the spatial equilibrium model, while in the second, either a monopolist or precautionary monopolist specification as outlined by Takayama and Judge (1971) is appropriate. The choice between a monopolist or precautionary monopolist specification will be governed by the possibility of resale among regions. A monopolist specification should be used when there is no resale among regions, ie strict restrictions on imports of a commodity onto the Australian domestic market apply. A precautionary monopolist specification is appropriate when there is the prospect of resale between regions and the possibility of the introduction of an arbitrager (as a potential threat), ie there are no limitations on imports onto the domestic market.

The rice industry is more likely to practice price discrimination on the domestic market rather than set a domestic quota, and as there is no trade protection from imports offered to the industry the precautionary monopolist specification is more applicable.

Both the quota and precautionary monopolist specifications of the spatial equilibrium model are presented for a three region problem (Tables 2 and 3). The quota model presented is fully developed and can be applied directly to problems involving price discrimination and price equalisation. The precautionary monopolist specification, however, follows that outlined by Takayama and Judge (1971) and requires further development to properly account for price equalisation from domestic and export markets.

A perfectly competitive model is adapted by imposing a domestic quota of θ in region 2, represented by the row RQ2 (Table 2). The shadow price on the quota is column PQ2. An important feature of this specification is that the shadow price from the quota is added to the supply price in region 2 (see row RSP2 and column PQ2 has a 1 value).

In the precautionary monopolist example, as there are no barriers to the importation of rice into Australia the rice industry can only practice price discrimination up to a certain point. If the price for domestic rice was set at a high enough level it may pay for arbitragers to enter the market by purchasing rice on the lower priced world market and selling on the domestic market. The introduction of these economic agents places certain restrictions on the regional price structure open to a monopolist. In a conventionalist monopolist model in equilibrium the difference between operative marginal revenue and marginal cost in region i must be equal to or less than transport cost, ie $\bar{\rho}_j - \bar{\rho}^i \leq t_{ij}$. This condition on the operative marginal revenues and marginal costs does not imply that the difference $p_j - p^i$ between demand price and average cost for any pair of regions will be equal to or less than the transport cost and thus the monopolist may increase his profits by practicing price discrimination. When product resale between regions is possible, if the regional prices resulting from the monopolist decision rules do not satisfy the condition

$$p_j - \bar{p}^i \leq t_{ij}$$

Table 2: Domestic quota specification of spatial equilibrium model

Min	DP1	DP2	DP3	SP1	SP2	SP3	PQ2	Y1	Y2	Y3	X1	X2	X3	X11	X12	X13	X21	X22	X23	X31	X32	X33		RHS
Y1								$-\omega_1$																
Y2									$-\omega_2$															
Y3										$-\omega_3$														
X1											η_1													
X2							-1					η_2												
X3													η_3											
Obj							θ	$-\lambda_1$	$-\lambda_2$	$-\lambda_3$	ν_1	ν_2	ν_3	t_{11}	t_{12}	t_{13}	t_{21}	t_{22}	t_{23}	t_{31}	t_{32}	t_{33}		
RDP1	-1							ω_1															$\leq$	$-\lambda_1$
RDP2		-1							ω_2														$\leq$	$-\lambda_2$
RDP3			-1							ω_3													$\leq$	$-\lambda_3$
RSP1				1							$-\eta_1$												$\leq$	ν_1
RSP2					1		1					$-\eta_2$											$\leq$	ν_2
RSP3						1							$-\eta_3$										$\leq$	ν_3
RX11	1			-1																			$\leq$	t_{11}
RX12		1		-1																			$\leq$	t_{12}
RX13			1	-1																			$\leq$	t_{13}
RX21	1				-1																		$\leq$	t_{21}
RX22		1			-1		-1																$\leq$	t_{22}
RX23			1		-1																		$\leq$	t_{23}
RX31						-1																	$\leq$	t_{31}
RX32						-1																	$\leq$	t_{32}
RX33						-1																	$\leq$	t_{33}
RY1								1						-1			-1			-1			$\leq$	0
RY2									1						-1			-1			-1		$\leq$	0
RY3										1						-1			-1			-1	$\leq$	0
RX1											-1			1	1	1							$\leq$	0
RX2												-1					1	1	1				$\leq$	0
RX3													-1							1	1	1	$\leq$	0
RQ2																		1					$\leq$	θ

Table 3: Precautionary monopolist specification of spatial equilibrium model

Min	DP1	DP2	DP3	SP1	SP2	SP3	Po12	Po13	Po21	Po23	Po31	Po32	Y1	Y2	Y3	X1	X2	X3	X11	X12	X13	X21	X22	X23	X31	X32	X33		RHS
Y1													$-2\omega_1$																
Y2														$-2\omega_2$															
Y3															$-2\omega_3$														
X1																$2\eta_1$													
X2																	$2\eta_2$												
X3																		$2\eta_3$											
Obj							ε_{12}	ε_{13}	ε_{21}	ε_{23}	ε_{31}	ε_{32}	$-\lambda_1$	$-\lambda_2$	$-\lambda_3$	ν_1	ν_2	ν_3	t_{11}	t_{12}	t_{13}	t_{21}	t_{22}	t_{23}	t_{31}	t_{32}	t_{33}		
RDP1	-1						ω_1	ω_1	$-\omega_1$		$-\omega_1$		$2\omega_1$															≤	$-\lambda_1$
RDP2		-1					$-\omega_2$		ω_2	ω_2		$-\omega_2$		$2\omega_2$														≤	$-\lambda_2$
RDP3			-1					$-\omega_3$		$-\omega_3$	ω_3	ω_3			$2\omega_3$													≤	$-\lambda_3$
RSP1				1												$-2\eta_1$												≤	ν_1
RSP2					1												$-2\eta_2$											≤	ν_2
RSP3						1												$-2\eta_3$										≤	ν_3
Po12													$-\omega_1$	ω_2														≤	ε_{12}
Po13													$-\omega_1$		ω_3													≤	ε_{13}
Po21													ω_1	$-\omega_2$														≤	ε_{21}
Po22														$-\omega_2$	ω_3													≤	ε_{23}
Po31													ω_1		$-\omega_3$													≤	ε_{31}
Po32														ω_2	$-\omega_3$													≤	ε_{32}
RX11	1			-1																								≤	t_{11}
RX12		1		-1																								≤	t_{12}
RX13			1	-1																								≤	t_{13}
RX21	1				-1																							≤	t_{21}
RX22		1			-1																							≤	t_{22}
RX23			1		-1																							≤	t_{23}
RX31						-1																						≤	t_{31}
RX32						-1																						≤	t_{32}
RX33						-1																						≤	t_{33}
RY1													1						-1			-1			-1			≤	0
RY2														1						-1			-1			-1		≤	0
RY3															1						-1			-1			-1	≤	0
RX1																-1			1	1	1							≤	0
RX2																	-1					1	1	1				≤	0
RX3																		-1							1	1	1	≤	0

then an arbitrager can make a profit by redistributing the product between regions. This affects the optimum structure of regional prices and thus equilibrium spatial demand quantities and flows.

The specification of the spatial equilibrium model has the following restriction placed by arbitragers:

$p_j - p_i \le t_{ij}$ or $\lambda_j - \omega_j y_j - \lambda_i + \omega_i y_i \le t_{ij}$ for $j \neq i$

This is conventionally rewritten as

$$G_o'\lambda - G_o\Omega y \le T_o$$

where $T_o = (t_{ij})$ for all $i \neq j$ with dimension $(n(n-1) \times 1)$,

$$G_o = \underset{(n(n-1)\times n)}{\begin{bmatrix} -1 & 1 & & & \\ -1 & & 1 & & \\ \vdots & & & \ddots & \\ -1 & & & & 1 \\ 1 & -1 & & & \\ & -1 & 1 & & \\ & \vdots & & \ddots & \\ & -1 & & & 1 \\ & \vdots & & & \\ 1 & & & & -1 \\ & 1 & & & -1 \\ & & \ddots & & \vdots \\ & & & 1 & -1 \end{bmatrix}},$$

$$G_o'\lambda = \begin{bmatrix} -\lambda_1 & + & \lambda_2 \\ -\lambda_1 & + & \lambda_3 \\ \vdots & & \\ -\lambda_1 & + & \lambda_n \\ & \vdots & \\ -\lambda_n & + & \lambda_1 \\ -\lambda_n & + & \lambda_2 \\ \vdots & & \\ -\lambda_n & + & \lambda_{n-1} \end{bmatrix}.$$

and

$$G_o\Omega = \begin{bmatrix} -\omega_1 & \omega_2 & & & \\ -\omega_1 & & \omega_3 & & \\ \vdots & & & \ddots & \\ -\omega_1 & & & & \omega_n \\ \omega_1 & -\omega_2 & & & \\ & -\omega_2 & \omega_3 & & \\ & \vdots & & \ddots & \\ & -\omega_2 & & & \omega_n \\ & \vdots & & & \\ \omega_1 & & & & -\omega_n \\ & \omega_2 & & & \\ & & \ddots & & \vdots \\ & & & \omega_{n-1} & -\omega_n \end{bmatrix},$$

$$(n(n-1)\times n)$$

The restrictions may be rewritten as

$$\begin{bmatrix} G_o\Omega & & \\ -I & & G_y \\ & I & G_x \end{bmatrix} \begin{bmatrix} y \\ x \\ X \end{bmatrix} + \begin{bmatrix} T_o & - & G_o\lambda \\ & & 0 \\ & & 0 \end{bmatrix} \geq 0,$$

and

$$(y^{'} x^{'} X^{'}) \geq 0.$$

This involves the introduction of the new rows and columns Po12 to Po32 in Table 3 where, for example row Po12, $\varepsilon_{12} = t_{12} - (-\lambda_1 + \lambda_2)$.

6. Summary

The rice industry's statutory power gives it the characteristics of a precautionary monopolist. Using the framework presented by Parish (1962) an outline of the changes in economic surplus associated with price equalisation under these circumstances is presented. This can involve increases in the domestic price, with a corresponding reduction in demand, higher returns to producers and larger production and exports than would occur under a perfectly competitive scenario. Importantly, some of the increase in exports may be sold at world market prices which are lower than the marginal cost of production represented by the industry's supply curve.

A methodology was presented, spatial equilibrium modelling, which is able to derive the equilibrium conditions under various assumptions regarding such a situation. Two alternative model specifications were presented, a domestic quota model and a precautionary monopolist model. Further work is required on the development of the precautionary monopolist spatial equilibrium model to better represent the manner in which the rice industry operates. A further development of this work would be to model the effects over time which could be done by using a recursive form of the spatial equilibrium model.

The domestic quota model presented, however, can correctly address price equalisation problems for industries that set domestic quotas in order to price discriminate. Once properly specified and run the spatial equilibrium model is able to determine the equilibrium price, quantity and trade flow conditions under various policy settings and thus lead to a measurement of changes to producer surplus, consumer surplus plus other welfare measures.

The methodology presented could be successfully applied to problems of this nature outside the rice industry. For instance, a recursive spatial equilibrium model could be developed to measure the welfare changes involved with successive wheat marketing plans as an alternative to an econometric approach (Myers, Piggott and MacAulay 1985). It is anticipated that such a methodology may become an important tool for measuring the social gains and losses of statutory marketing arrangements.

References

Australian Bureau of Agricultural and Resource Economics (1993), Commodity Statistical Bulletin, ABARE Project 53.013, Table 64, p.62, Commonwealth of Australia.

Australian Bureau of Statistics (various), Apparent Consumption of Selected Foodstuffs, Australia, Cat.4315.0.

______, Estimated Resident Population by Country of Birth, Age and Sex, Australia, Cat.3221.0.

______, Average Retail Prices of Selected Items for Eight Capital Cities, Australia Cat.6403.

Bureau of Agricultural Economics (1987), *The Rice Industry: A BAE Submission to the IAC*, AGPS, Canberra, July.

Cramer, G.L., Wailes, E.J. and S. Shui (1993), 'Impacts of liberalising trade in the world rice market', *American Journal of Agricultural Economics* 75, 219-26.

Curthoys, C., Marshall, G. and Jones, R. (1994), Coleambally Land and Water Management Plan Economics of On-farm Proposals, A Report to the Community Working Group of the Coleambally Land and Water Management Plan.

Gardiner, W.H., Ronigen, V.O. and Liu, K (1989) Elasticities in the Trade Liberalisation Database USDA, Economic Research Service Staff Report AGES8920, Washington, DC.

George, K.D. and Shorey, J. (1978), *The Allocation of Resources: Theory and Practice*, George Allen and Unwin, London.

Godden, D.P. (1978), 'The resource misallocation costs of equalisation - again', *Review of Marketing and Agricultural Economics* 46(2), 141-49.

Houck, M. (1986), *Elements of Agricultural Trade Policies*, Macmillan, New York.

Industries Assistance Commission (1987), *The Rice Industry*, Report No. 407, AGPS, Canberra, October.

Industry Commission (1990), *Statutory Marketing Arrangements for Primary Products*, Draft Report, AGPS, Canberra.

Jones, R.E. (1991), Optimal irrigation water allocation and supply reliability in the Murrumbidgee Valley, unpublished M.Econ dissertation, Department of Agricultural Economics and Business Management, University of New England, Armidale.

Kingwell, R. (1994), 'Effects of tactical responses and risk aversion on farm wheat supply', *Review of Marketing and Agricultural Economics* 62(1), 29-42.

Kraft, D., Piggott, R. and Wright, V. (1991), *Review of the Rationale of the Rice Marketing Board*, A report to the New South Wales Minister for Agriculture and Rural Affairs, Centre for Advanced Training in Agricultural Economics, University of New England, Armidale, January.

Lewis, I (1994), *Fresh Potato Marketing Research*, Horticultural Research and Development Corporation, PT201.

Longworth, J.W. (1966), 'The Australian wheat industry stabilization scheme: An analytical model', *Economic Record* 42(98), 244-55.

MacAulay, T.G., Batterham, R.L. and Fisher, B.S. (1988), Cubic programming and the solution of spatial trading systems, Paper presented to the 32nd Annual Conference of the Australian Agricultural Economics Society, Melbourne, February.

Myers, R.J., Piggott, R.R and MacAulay, T.G. (1985), 'Effects of past Australian wheat price policies on key industry variables', *Australian Journal of Agricultural Economics* 29(1), 1-15.

Parish, R.M. (1962), 'The costs of protecting the dairy industry', *The Economic Record* 38(85), 167-82.

Quilkey, J.J. (1974), *The demand for rice and its relevance for price and promotion policies*, Department of Agricultural Economics, University of New England, Armidale NSW

Rice Marketing Board for the State of New South Wales (1993), *Annual Report*, Leeton.

Takayama, T. and Judge, G.G. (1964), 'Equilibrium among spatially separated markets: A reformulation', *Econometrica* 32, 510-24.

_____ (1971), *Spatial and Temporal Price Allocation Models*, North-Holland Publishing Co., Amsterdam.

Tomek, W.G. and Robinson, K.L. (1981), *Agricultural Product Prices*, Cornell University Press, Ithaca.

United States Department of Agriculture (1994), *Rice Situation and Outlook Report*, Yearbook Issue, Economic Research Service, RCS-70 July

Wall, L., Marshall, G., Jones, R., and Darvall. D. (1994), Economics of on-farm proposals: Berriquin Land and Water Management Plan, A Report to the Berriquin Community Working Group.

Wohlgenant, M.K. and Haidacher R.C. (1991), *Approaches to Modelling Retail-Farm Price Spreads and Derived Demand Relationships for Food Commodities - A Selected, Annotated Bibliography*, Economic Research Service, United States Department of Agriculture.