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Was the Australian Meat and Live-stock Corporation's advertising efficient?

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A theory of the allocation of producer levies earmarked for downstream promotion is developed and applied to quarterly series (1970:2–1988:4) on red-meats advertising by the Australian Meat and Live-stock Corporation. Robust inferences about program efficiency are contained in the coefficients of changes in promotion effort regressed against movements in farm price and quantity. Empirical evidence of program efficiency is inconclusive. While the deeper issue of efficient disbursement of funds remains an open question, there is evidence, at least, of efficient taxation.

1. Introduction

The privileged status of agriculture in modern societies has resulted in a variety of innovations designed to protect producer returns. One of these, the topic of this article, is mandatory commodity promotion. The essential features of this policy are threefold: first, promotion output targeted for downstream markets is the result of a production process; second, the production process creating the output incurs a cost; third, in order to raise the funds necessary to cover this cost a tax must be enacted. Given their mandatory nature, the magnitudes of the costs involved, and the level of uncertainty over their specific impacts, commodity promotion programs have

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recently come under close scrutiny. One case in point is the Australian Meat and Live-stock Corporation's promotion of red meats. A recent *Sydney Morning Herald* article reflects some of the essential concerns:

> A giant question mark is hanging over the future of one of the country's most highly-acclaimed and cashed-up marketers, the Australian Meat and Live-stock Corporation. For the past two decades the AMLC has been the key industry body collecting levies from producers to pay for the integrated but generic marketing of red meat products both in Australia and internationally . . . While the campaigns, all created by the AMLC's long-standing ad agency, The Campaign Palace, have scooped industry awards pools in recent years, a tough market has started producers questioning the value of the AMLC and the $78 million in levies it absorbs annually . . . But despite the extremely sophisticated marketing activities of the AMLC, consumption of red meat in Australia is still declining. According to the Australian Bureau of Statistics, per capita beef consumption in Australia was 41.4 kg in 1986, less than a decade later it had dropped to 35.1 kg in 1995. Lamb has plummeted from 16.9 kg per capita in 1986 to 11.4 kg in 1995.
>
> (*The Sydney Morning Herald,* 28 November 1996)

In this context a question arises that generates considerable scope for empirical investigation, namely:[1,2] Was the Australian Meat and Live-stock Corporation's advertising efficient?

This article derives theory and econometrics for answering this question. A methodology is proposed that is applicable to time series on farm price and quantity movements and changes in promotion expenditures. The approach is grounded in the classic work on optimal allocations of advertising budgets (Dorfman and Steiner 1954; Nerlove and Waugh 1961) that has spawned a substantial literature on allocations of program expenditures (Kinnucan 1996; Kinnucan and Christian 1997), econometric estimation of allocation rules (Liu and Forker 1990; Haliburton and Henneberry 1995), trade extensions (Goddard and Conboy 1993) and extensions to explicitly incorporate eccentricities of commodity programs (Ding and Kinnucan 1996; Wohlgenant and Clary 1994). A pertinent neglect

[1] Posed in a previous draft, 'Is the Australian Meat and Live-stock Corporations' advertising efficient?', a change in tense was mandated by the fact that program expenditures ceased during the early part of 1997 and the Corporation was disbanded in June 1998.

[2] Throughout this article the term 'efficient' refers to the maximum net surplus generated from the promotion program or the maximum value of the benefit-cost ratio computed from the program.

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in much of this literature is the effect on program costs of the dead-weight burden of tax collection. In this regard, the graphical treatments in Chang and Kinnucan (1991); Alston, Carman and Chalfant (1994); and Holloway (1998) are useful in motivating the key ideas. This article builds on these works in an effort to construct a robust methodology with reference to the tax problem, but more especially, the data constraints one typically faces in examining program efficiency.

The method we propose is attractive for three reasons. First, it is simple to implement, requiring for its test of efficiency that the values of particular parameters in a set of linear regressions are, statistically, zero. Second, the data series required to implement the tests are usually available from public sources, making the theory and procedures applicable to a wide array of markets and a diverse set of programs. Third, implementation of the theory follows, closely, established empirical procedures (Wohlgenant 1989; Holloway 1991) that integrate the fundamental theory of food marketing (Muth 1964; Gardner 1975) with an extensive literature on the qualitative impacts of research and promotion in vertically related markets (Freebairn, Davis and Edwards 1982, 1983; Alston and Scobie 1983; Holloway 1989; Voon and Edwards 1991, 1992; Wohlgenant 1993; Piggott, Piggott and Wright 1995). In this literature, authors have focused exclusively on the distribution of the benefits of particular programs. Here, this work is extended to explicitly incorporate costs, enabling the computation of cost-benefit formulae for an actual program. The cost issue has, no doubt, been ignored due to the lack of reliable estimates of research costs. For example, neither the works of Chang and Kinnucan nor Alston *et al.* tackle the costs issue. It is shown here, however, that, given a set of modest assumptions — assumptions no more restrictive than the ones invoked in the literature — the problem of non-availability of costs can be circumvented.

The second section introduces notation and presents methodology while the third section discusses implementation of the theory. The fourth section presents the empirics, and in the final section the conclusion is shown.

2. Downstream promotion cost-benefit analysis

Our objectives are twofold. The first objective is to derive and analyse a prototype, efficient promotion program. The second objective is to derive a statistical procedure for comparing the level of promotion implied by the prototype and the level that we actually observe empirically, that is, between the normative and the positive levels of investment in promotion. At this point it is useful to draw comparisons between the present, normative approach, and the one in the classic paper by Nerlove and Waugh (1961).

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The Nerlove-Waugh model, like the present one, is a normative model because an efficiency objective is the focus. The difference between it and the present model is simply the neglect of the tax issue in generating the funds necessary to cover promotion costs. This distinction is important for two reasons. First, neglecting the tax issue necessarily affects the optimality formulae that characterise the optimal level of investment in promotion activities. Second, most promotion schemes (including the present one) are financed by a self-imposed levy. Nerlove and Waugh assume that the funds required to raise promotion revenues are obtained elsewhere; but here — as in Chang and Kinnucan (1991); Alston *et al.* (1994) and Holloway (1998) — we assume that the tax revenues are raised from a levy on the commodity in question.[3] Finally, unlike the contributions in the latter papers, we extend the conceptual framework to show how the rules can be applied to a vertical marketing system and can be tested empirically. These are our principal contributions.

With these distinctions at hand, the plan of the inquiry can be summarised. Let θ denote the level of promotion effort in the downstream market, $C(\theta)$ the cost incurred in producing it, and τ the levy required to cover promotion expenditures. The question at issue is the difference, if any, between empirically observable levels of θ and some optimal, but unknown level, θ^*. Three objectives arise in this endeavour. The first, the topic of this section, is a characterisation of θ^*. The second, the topic of the third section, is the derivation of a statistical method for assessing differences between θ and θ^*. The third, studied in the fourth section, is the informational content of the empirical applications.

Consider the following farm-to-retail system. Primary producers supply output to a marketing sector which, in turn, combines the farm product with another productive factor. The resulting product is sold in a terminal market, wherein promotion occurs. At this point, alternative interpretations of θ arise. For example, in the case of advertising using television or radio media, θ may be interpreted as the time duration of commercials. In the case of magazine or newspaper advertising, θ could represent pages of periodicals devoted to the product in question. Measurement issues aside, producers agree to share any benefits that accrue, as well as any costs incurred. Let $C(\theta)$ denote variable costs of promotion and assume, for $\theta \geq 0$,

[3] These sentiments are reiterated in other words by Alston, Carman and Chalfant: 'Like Dorfman and Steiner (1954), Nerlove and Waugh (1961) modeled a case where the advertising is funded in a lump-sum way, unrelated to output, with the implication that all of the advertising cost is borne by producers. That approach has been adopted in many subsequent studies of primary product promotion. Here we will extend the Nerlove-Waugh model to the situation where advertising is funded by a per unit check-off' (1994, p. 157).

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$$C(\theta) \equiv \kappa\theta, \tag{1}$$

where $\kappa > 0$, so that constant-returns-to-scale are present. This formulation will play a key role in the construction of an explicit measure of promotion effort. For this reason, it is important to keep in mind the importance of the constant-returns-to-scale assumption as we progress. It is motivated by two arguments. The first is that demand for promotion resources by the AMLC is small in relation to total demand. Therefore, changes in AMLC demand are unlikely to affect the per-unit cost, κ. Second, free entry and exit into the promotion industry ensure pricing at minimum average-total-costs, at which point local returns to scale are constant.

The existence of costs, $C(\theta)$, draws the inquiry to the question of the tax rate, τ, that must be enacted in order to cover promotion expenditures. The problem is considered graphically, and at some length, in Chang and Kinnucan (1991) and in Alston *et al.* (1994), but a concise treatment in a single graphic is developed in Holloway. In order to conserve space, the reader is referred to Holloway (1998). His argument draws us to the conclusion that, in order for the program to be optimal, marginal adjustments in price must be zero.[4] Later in this article, proportional-change, comparative-statics are applied, in which ad-valorem taxes are more amenable to analysis. Whether an ad-valorem or a per-unit tax is assumed depends, of course, on the program in question;[5] but the issue is moot, for two reasons. First, the qualitative impacts of the two instruments are identical under price-taking, which is assumed throughout. Second, the econometric procedures employed circumvent use of data on tax rates.

Turning to the program, let w denote the farm-gate price of the commodity in question. Then, with τ the ad-valorem tax rate, marketing agents pay $w(1+\tau)$ for each unit of the farm commodity, x, and total revenues from tax collection are

$$R(\tau, \theta) \equiv \tau w(\tau, \theta)x(\tau, \theta), \tag{2}$$

Here, it is acknowledged, explicitly, that both the rate of taxation and the level of promotion effort affect farm price and quantity. When a levy

[4] As a reviewer notes: 'The intuition is simply that the checkoff is optimized when the upward shift in supply associated with the tax is exactly offset by an upward shift in demand associated with the advertising so that at the margin there is no change in farm price (net of the tax).' The result is reiterated, in other words, by Alston, Carman and Chalfant: 'producers will prefer to increase the check-off and advertising so long as at the margin, demand shifts up by more than the supply so that equilibrium quantity rises with an increase in producer surplus' (1994, p. 157).

[5] This issue is further complicated by the fact that farm-gate levies are typically imposed for a variety of purposes including, but not restricted to, commodity promotion.

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is imposed, producers receive revenues from two sources. The first is the market; the second is from tax collection. In the market, producer benefits rise monotonically with increases in θ and fall monotonically with increases in τ. In tax collection, program revenues may rise or fall with respect to θ and τ. Costs, of course, rise unambiguously with respect to θ. Under the null hypothesis of program efficiency, the normative problem that we examine is the same as the problem confronting surplus-maximising executives empowered with the allocation of program revenues. Later we consider the empirical evidence in favour of this null hypothesis but, for now, we focus on the analysis of this normative problem.[6] Conceptually, this amounts to balancing the offsetting effects of the tax and promotion instruments in order to maximise producer returns, which is the sum of three components, namely, the area between price and the inverse supply schedule,

$$w = S(x); \tag{3}$$

total revenues from tax collection; and the negative of the costs incurred in promoting the product. Accordingly, we define an efficient promotion investment as the one that maximises this surplus objective, subject to the constraint that tax revenues are sufficient to finance the scheme, or, more formally, the solution to:

$$\text{Problem 1:} \quad \max_{\tau,\theta}: \Psi(\tau,\theta) \equiv w(\tau,\theta)x(\tau,\theta) - \int_0^{x(\tau,\theta)} S(s)\,ds + R(\tau,\theta) - C(\tau,\theta)$$
$$\text{subject to:} \quad R(\tau,\theta) \geq C(\tau,\theta), \tag{4}$$

which, we assume, is locally unique. Restricting attention to schemes in which the funding constraint is binding, the constraint equality,

$$R(\tau,\theta) = C(\theta), \tag{5}$$

can be used to express the tax rate as a function of promotion effort, and write $\tau = \tau(\theta)$. Accordingly, Problem 1 simplifies to

$$\text{Problem 2:} \quad \max_{\theta}: \Psi(\theta) \equiv w(\tau(\theta),\theta)x(\tau(\theta),\theta) - \int_0^{x(\tau(\theta),\theta)} S(s)\,ds. \tag{6}$$

[6] Some confusion may arise over differences between normative and positive interpretations of the scheme. The approach thus far in the article, we stress, is strictly normative. That is, we are asking simply what the scheme should look like in the event that efficient investment is obtained. Later we ask the (empirical) question about whether the observed and the optimal investment levels are the same.

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Using subscripts to signify partial derivatives, the necessary condition for a maximum is

$$(w_\tau x + wx_\tau - wx_\tau)\tau_\theta + (w_\theta x + wx_\theta - wx_\theta) = 0, \tag{7}$$

and, thus, from the point of view of the scheme's members, the investment level of θ is efficient when it solves equation 7. In order to connect this result with the intuition that the optimum reflects zero marginal adjustment in price, recall the dependence $w = w(\tau(\theta), \theta)$. Accordingly, the total derivative is $\Delta w = (w_\tau \tau_\theta + w_\theta)\Delta\theta$ and, from cancelling terms in equation 7, implies that price is invariant to marginal adjustments in the program. Despite this intuitive link it is useful for later purposes to manipulate equation 7 into a form that is more amenable to empirical analysis and leads naturally to empirically refutable propositions about the efficient level of investment in the commodity promotion program. Four results that are fundamental in this endeavour are the following:

Lemma 1: $\tau_\theta = \dfrac{C_\theta - R_\theta}{R_\tau}$.

Lemma 2: $w_\tau x_\theta = w_\theta x_\tau$.

Corollary 1: $E_{w\tau}E_{x\theta} = E_{w\theta}E_{x\tau}$.

Lemma 3: $\kappa\theta = \tau wx$.

Lemma 1 defines the rate of change in the tax rate when promotion effort adjusts. It follows from differentiating both sides of equation 5 and assuming $R_\tau \neq 0$. Lemma 2 follows from taking derivatives along the inverse supply schedule (equation 3). When the tax rate changes, $w_\tau = S_x x_\tau$, and when promotion effort adjusts, $w_\theta = S_x x_\theta$. Combining these two results yields the equality in the lemma. Corollary 1 follows from writing the last result in terms of elasticities, wherein $E_{\alpha\beta} \equiv \alpha_\beta \beta/\alpha$. Finally, lemma 3 follows from combining the definition of costs (equation 1) with the definition of program revenues (equation 2) in the constraint equality (equation 5).

With these results at hand, begin, in equation 7, by cancelling terms, substituting from lemma 1, and multiplying through by $R_\tau \neq 0$. This yields

$$w_\tau x(C_\theta - R_\theta) + w_\theta x R_\tau = 0. \tag{8}$$

Next, divide through by x and make use of the definitions (from equation 1) $C_\theta \equiv \kappa$ and (from equation 2) $R_\tau \equiv wx + \tau w_\tau x + \tau wx_\tau$ and $R_\theta \equiv \tau w_\theta x + \tau wx_\theta$ to obtain

$$w_\tau(\kappa - \tau w_\theta x - \tau wx_\theta) + w_\theta(wx + \tau w_\tau x + \tau wx_\tau) = 0. \tag{9}$$

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Cancelling terms and invoking lemma 2,

$$w_\tau \kappa + w_\theta w x = 0. \tag{10}$$

Dividing through by wx and invoking lemma 3,

$$w_\tau \tau + w_\theta \theta = 0. \tag{11}$$

Finally, normalising on w yields

$$E_{w\tau} + E_{w\theta} = 0, \tag{12}$$

where $E_{w\tau} \equiv w_\tau \tau / w$ and $E_{w\theta} \equiv w_\theta \theta / w$ denote elasticities depicting the effects on farm price of proportional changes in the policy instruments.

The restriction in equation 12 is appealing for three reasons. First, it is highly intuitive. It states as a necessary condition for program efficiency that the marginal benefits of promotion equal the marginal costs of obtaining them. Because producer surplus is monotonic in farm price, the marginal effects of changes in τ and θ can be computed (via the chain rule) from their impacts on the reduced-form for price. This leads naturally to equation 12 and to a second basis of appeal for the restriction.

Elasticities like $E_{w\tau}$ and $E_{w\theta}$ are the focus of attention in a distinct literature devoted to farm-to-retail links. This work has its roots in an early paper by Muth (1964) and an initial application to agriculture by Gardner (1975). Subsequently, the Muth-Gardner model has provided a basis for numerous investigations in vertical marketing channels, including quantification of downstream research benefits (Alston and Scobie 1983; Freebairn, Davis and Edwards 1983; Holloway 1989), characterisation of food-marketing efficiency (Kilmer 1987), and the inclusion of marketing-group behaviour in robust estimation of food demand (Wohlgenant 1989). The latter work is particularly relevant and leads naturally to a third basis of appeal for the restriction in equation 12.

As demonstrated by Wohlgenant (1989), estimates of reduced-form effects like $E_{w\tau}$ and $E_{w\theta}$ can be retrieved from a simple, econometric procedure that regresses first differences in the logarithms of farm price against first differences in the logarithms of the instruments τ and θ. Consequently, the theory that generates equation 12 can be tested, statistically, in an appealing way, as a linear restriction imposed across two coefficients in a simple regression. This regression, and all its refinements, are the focus of the next section. Before turning to examine this regression, however, two points about the analysis are noteworthy. First, the analysis is independent of whether we substitute from equation 5 $\theta = \theta(\tau)$ instead of $\tau = \tau(\theta)$. This result is easily demonstrated by reworking the analysis following the re-specification of equation 6 that evolves from substituting $\theta = \theta(\tau)$ instead of $\tau = \tau(\theta)$ in

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equation 4. Second, its significance is worth emphasising because this choice will later prove convenient in endogenizing either θ or τ.[7]

3. Implementation

Estimation is facilitated in three steps. The first considers the set of quasi-reduced forms that characterise equilibrium in the marketing channel. The second imposes on this system an identity implied by the budget constraint (equation 5 and lemma 3). The third studies the reduced-form implied by this structural system and identifies a set of restrictions that are equivalent to the restriction in equation 12.

Using p to denote the price of the food product, and y its quantity, marketing equilibrium in the presence of promotion can be written as the set of equations

$$\begin{array}{rcl} p & = & \Re^1(\tau, \theta, \mathbf{z}), \\ y & = & \Re^2(\tau, \theta, \mathbf{z}), \\ \dots & & \dots \\ w & = & \Re^{M-2}(\tau, \theta, \mathbf{z}), \\ x & = & \Re^{M-1}(\tau, \theta, \mathbf{z}), \end{array} \tag{13}$$

where $\Re^1(\cdot)..\Re^{M-1}(\cdot)$ denote a set of quasi-reduced forms and $\mathbf{z} \equiv (z_1, z_2 \dots z_{N-2})'$ represents the effects of other variables that impact the equilibrium. This system leaves unspecified the remaining equations comprising the link between the farm and terminal markets. In view of this, the specification in equation 13 is quite general. It would represent a true reduced form were it not for the fact that tax rates and promotion effort are related by the budget constraint in lemma 3. In this case, lemma 3 and equation 13, together, comprise an M-dimensional structural system, containing $p, y \dots w, x$ and either the tax rate, τ, or the level of promotion effort, θ, as endogenous variables. In this context an age-old question arises: can relevant information be retrieved from the reduced form?

[7] A reviewer questions the appropriateness of the assumption that the tax rate can be considered endogenous. It is clear from the interchange $\theta = \theta(\tau)$ and $\tau = \tau(\theta)$, above, that when revenues from tax collection bind promotion costs, one of the instruments is endogenous. This is illustrated in other terms through the implicit differentiation in lemma 1, but it is also observed as providing the basis for all of the comparative statics that are undertaken in Alston, Carman and Chalfant (1994, pp. 157–9). Once again, when the revenue constraint binds, either the level of promotion effort, θ, or the rate of taxation, τ, is endogenous in the system of equations characterising optimal promotion decisions in the vertical marketing channel. The point is important and is reiterated formally in the equations that follow.

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In response, a set of transformations follow. They are designed for the purpose of retrieving from the reduced-form the restriction in equation 12 or, at least, an economically equivalent condition. Displacing the equations of interest by a sequence of Taylor-series expansions and expressing the resulting derivatives in proportional-change terms, we obtain, from equation 3,

$$\begin{array}{lllllllllll}\tilde{p} & = & E_{p\tau}\tilde{\tau} & + & E_{p\theta}\tilde{\theta} & + & E_{pz_1}\tilde{z}_1 & + & \ldots & + & E_{pz_{N-2}}\tilde{z}_{N-2},\\ \tilde{y} & = & E_{y\tau}\tilde{\tau} & + & E_{y\theta}\tilde{\theta} & + & E_{yz_1}\tilde{z}_1 & + & \ldots & + & E_{yz_{N-2}}\tilde{z}_{N-2},\\ \ldots & & \ldots & & & & & & & & \\ \tilde{w} & = & E_{w\tau}\tilde{\tau} & + & E_{w\theta}\tilde{\theta} & + & E_{wz_1}\tilde{z}_1 & + & \ldots & + & E_{wz_{N-2}}\tilde{z}_{N-2},\\ \tilde{x} & = & E_{x\tau}\tilde{\tau} & + & E_{x\theta}\tilde{\theta} & + & E_{xz_1}\tilde{z}_1 & + & \ldots & + & E_{xz_{N-2}}\tilde{z}_{N-2},\end{array} \tag{14}$$

and, from lemma 3,

$$\tilde{\kappa} + \tilde{\theta} = \tilde{\tau} + \tilde{w} + \tilde{x}, \tag{15}$$

where $\tilde{v} \equiv \Delta v/v$ denotes proportional change in variable v. With τ endogenous, the system is

$$B\mathbf{y} = \Gamma\mathbf{x}, \tag{16}$$

where $y_{(M\times 1)} \equiv (\tilde{p}, \tilde{y},.., \tilde{w}, \tilde{x}, \tilde{\tau})'$ denotes an M-vector of movements in the endogenous variables, $\mathbf{x}_{(N\times 1)} \equiv (\tilde{\theta}, \tilde{z}_1,.., \tilde{z}_{N-2}, \tilde{\kappa})'$, denotes an N-vector of movements in the exogenous variables, and the coefficient matrices $B_{(M\times M)}$ and $\Gamma_{(M\times M)}$ are defined, respectively, as follows

$$B \equiv \begin{pmatrix} 1 & & & & -E_{p\tau} \\ & 1 & & & -E_{y\tau} \\ & & .. & & .. \\ & & 1 & & -E_{w\tau} \\ & & & 1 & -E_{x\tau} \\ & & 1 & 1 & 1 \end{pmatrix}, \tag{17}$$

and

$$\Gamma \equiv \begin{pmatrix} E_{p\theta} & E_{pz_1} & .. & E_{pz_{N-2}} & \\ E_{y\theta} & E_{yz_1} & .. & E_{yz_{N-2}} & \\ .. & .. & .. & .. & .. \\ E_{w\theta} & E_{wz_1} & .. & E_{wz_{N-2}} & \\ E_{x\theta} & E_{xz_1} & .. & E_{xz_{N-2}} & \\ 1 & & & & 1 \end{pmatrix}. \tag{18}$$

The solution in equation 16 is

$$\mathbf{y} = \Psi\mathbf{x}, \tag{19}$$

where $\Psi_{(M\times N)}$, defined

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$$\Psi \equiv \begin{pmatrix} \pi_{p\theta} & \pi_{pz_1} & .. & \pi_{pz_{N-2}} & \pi_{p\kappa} \\ \pi_{y\theta} & \pi_{yz_1} & .. & \pi_{yz_{N-2}} & \pi_{y\kappa} \\ .. & .. & .. & .. & .. \\ \pi_{w\theta} & \pi_{wz_1} & .. & \pi_{wz_{N-2}} & \pi_{w\kappa} \\ \pi_{x\theta} & \pi_{xz_1} & .. & \pi_{xz_{N-2}} & \pi_{x\kappa} \\ \pi_{\tau\theta} & \pi_{\tau z_1} & .. & \pi_{\tau z_{N-2}} & \pi_{\tau\kappa} \end{pmatrix}, \tag{20}$$

satisfies $\Psi = B^{-1}\Gamma$. Finally, focusing attention on the first coefficients in the last three equations in equation 19, applying Cramer's rule in equation 16, and using corollary 1,

$$\begin{aligned} \pi_{w\theta} &\equiv \frac{E_{w\tau} + E_{w\theta}}{|B|} \\ \pi_{x\theta} &\equiv \frac{E_{x\tau} + E_{x\theta}}{|B|} \\ \pi_{\tau\theta} &\equiv \frac{1 - E_{w\theta} - E_{x\theta}}{|B|} \end{aligned} \quad , \tag{21}$$

where $|B| \equiv 1 + E_{w\tau} + E_{x\tau}$.

The correspondences in equation 21 provide the basis for empirical investigations of the proposition in equation 12. They are the focus of attention in the remainder of the article. From equation 12, the first effect is zero when the level of θ is efficient. But since the second condition is a monotonic transformation of the first (in which a supply elasticity, $\eta > 0$, acts as the scale factor), it too will be zero under the null hypothesis of efficient disbursement of funds. Finally, the third coefficient equals one when the null hypothesis is valid. Therefore, three tests of the efficiency hypothesis are available from examining the coefficient of promotion effort in the reduced-form equations depicting movements in farm price, farm quantity, and the ad-valorem tax implied by the program. The tests are intuitive, are simple to implement, and are derived from a very general theory of promotion that lends itself readily to empirical analysis. In the appendix, we show how this theory and its empirical implementation extend readily to multimedia situations, to difference formulations, and to trade equilibria.

Econometric application of the theory is facilitated by interpreting observations in the time series as repeated experiments in equation 19, which hold stochastically, according to the relation

$$\mathbf{Y} = \mathbf{X}\Pi + \mathbf{V}, \tag{22}$$

where, in familiar notation (e.g. Drèze and Richard 1993, p. 519) $\mathbf{Y}_{(T\times M)}$ is a matrix of observations on $\mathbf{y}'$; $\mathbf{X}_{(T\times N)}$ is a matrix of observations on $\mathbf{x}'$; $\Pi_{(N\times M)} \equiv \Psi'$; and the error matrix, $\mathbf{V}_{(T\times M)}$ is assumed to be distributed

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$N(\mathbf{0}, \Omega \otimes \mathbf{I_T})$, where $\Omega_{(M \times M)}$ specifies covariance among the columns of **V**. In view of the identity in lemma 3, at least one column in **V** is a linear combination of two others, implying that the matrix, Ω, is singular. Therefore, in the applications that follow, the tax-rate equation is excluded from the estimation, and attention is restricted to the coefficients $\pi_{w\theta}$ and $\pi_{x\theta}$.

4. Applications

Two applications are presented. The first considers the beef-marketing channel and the second considers the lamb sector. Both applications are studied independently and both apply quarterly observations from the period 1970:2–1988:4. During this time-frame, generic advertising of red meats rose dramatically in Australia, as it did elsewhere, notably in Canada and the United States (Piggott *et al.* 1996). Nominal expenditures by the AMLC increased from period lows of less than 500 000 A$ to period highs during the late 1980s of close to four million dollars (or close to three-quarters of a million dollars, or a 50 per cent increase, in real terms). In the period studied, the AMLC was one of three statutory bodies funded by levies on live-stock producers and meat processors. One agency, most recently known as the Meat Research Corporation (MRC), was responsible for research and development activities and levy funds for its operation were matched by contributions from the Commonwealth government. The other agency, most recently known as the Meat Industry Council (MIC), was responsible for policy matters. The principal responsibility of the AMLC was marketing and promotion, including expenditures on advertising, merchandising, product public relations, nutrition, product development, education, food service, market research and technical services (Ball and Dewbre 1989). In this regard, direct application of the theory requires two problems to be addressed. The first stems from the fact that the three bodies receive funds from a common set of levies. At first glance, this may pose problems for interpreting the allocation decision in line with the theory proposed above. However, the levies paid to each fund organisation are essentially separate and they can be regarded as independent from one another. A more comprehensive analysis, incorporating the allocation decisions by the other statutory bodies, lies outside the scope of the current effort.

On the second count, a problem arises in disentangling the effects of the allocations across the relevant commodity groups, including buffalo and goats, but, most importantly, beef and sheep-meats. The approach used below is to apply the aggregate data on promotion effort, but study the sectors of interest independently. Three precedents guide this choice. One is the tradition (Nerlove and Waugh 1961; Chang and Kinnucan 1991; Alston *et al.* 1994; and Holloway 1998) of focusing on a single sector; the second is

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the pedagogic advantage of aligning the empirical model as closely as possible to these intellectual foundations of the theory; and the third is the fact that the magnitude of the bias can be assessed quite easily. The more complicated issue of correcting for this bias is considered only in the event that significance is obtained. For readers who are interested in the program effects on the aggregate surplus across the sheep- and beef-meat sectors, it is not too difficult to demonstrate (Appendix 1 available upon request) that the independent application to each of the two sectors gives upper and lower bounds on the level of promotion that maximises aggregate surplus. [8]

Both applications apply data on farm price, farm quantity and a set of relevant instruments. Fundamental in this regard is the construction of two additional series. The first is an aggregate measure of promotion effort, $\theta_t, t = 1, 2..T$; the second is a corresponding set of observations on the real, per-unit costs of advertising, κ_t. Nominal advertising expenditures are incurred across three media forms: television broadcasts, A_{Tt}, radio transmissions, A_{Rt} and newspaper articles, A_{Nt}. Associated with these nominal expenditures are the corresponding real expenditures, θ_{Tt}, θ_{Rt} and θ_{Nt}. Hence, aggregate program revenues are:

$$R_t = A_{Tt} + A_{Rt} + A_{Nt}, \quad t = 1, 2..T, \tag{23}$$

and an index of aggregate promotion effort could be constructed as the share-weighted sum of the three media allocations, with shares of nominal expenditures used as the weights. That is:

$$\theta_t = \sum_{i=1}^{3} \theta_{it} \frac{A_{it}}{R_t}, \quad t = 1, 2..T, \tag{24}$$

where the corresponding deflator is

[8] A reviewer has argued for the inclusion of so-called externalities resulting from the promotion program. There are two potential sources of bias in failing to account for these effects. Both sources are relevant to our findings, but both, it turns out, can be detected and rationalised easily. One externality arises from the fact that the promotion program (targeted, generically, at 'red meats') may have an optimum over the aggregate of the surpluses in the sheep-meat and beef-meat sectors that departs substantially from the optimum of each single sector. In this case, a single-sector focus biases the estimate of the optimum. However, it turns out that the aggregate optimum must be bounded by the optimum for each single sector expenditure level (a simple, deductive proof is presented in Appendix 1). Thus, where such bias is a concern, we are at least able to locate the range of the aggregate optimum. The second source of bias arises from ignoring cross-commodity impacts of promotion. In this case we are concerned about the derivative impacts of promotion in affecting price in one sector, then consumption of substitute goods in the other, which in turn has an impact on price in that sector, and so on. But where these impacts are thought to be important, the simultaneity that is necessary for their existence is easily tested. The appropriate tests are discussed subsequently.

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$$\kappa_t = \frac{R_t}{\theta_t}, \quad t = 1, 2..T. \tag{25}$$

However, as correctly pointed out by a reviewer, aggregations of this type may impute bias when consumer responses to the separate media forms are not homogeneous. The remedy in this case is to treat each media type as a separate allocation and test for homogeneity using a conventional F test. In the estimations that follow, we employ this step-wise approach to the aggregation problem. In this regard a problem arises in the interpretation of the coefficients of the separate promotion variables. The theory, recall, is developed only for the case of an aggregate promotion variable; thus, the question arises as to the applicability of this theory to the multi-media promotion program of the AMLC. In Appendix 2 (available upon request) we show that, in the context of a set of multiple allocations, $\theta_1, \theta_2 \ldots \theta_K$, the results obtained for the univariate case extend easily to multiple media. In particular, the multi-media versions of key equations 12 and 21 become, respectively:

$$E_{w\tau} + E_{w\theta_i} = 0, \quad i = 1, 2..K, \tag{26}$$

and

$$\left.\begin{aligned} \pi_{w\theta_i} &\equiv \frac{\alpha_i E_{w\tau} + E_{w\theta_i}}{|B|} \\ \pi_{x\theta_i} &\equiv \frac{\alpha_i E_{x\tau} + E_{x\theta_i}}{|B|} \\ \pi_{\tau\theta} &\equiv \frac{\alpha_i - E_{w\theta_i} - E_{x\theta_i}}{|B|} \end{aligned}\right\}, \quad i = 1, 2..K, \tag{27}$$

where $\alpha_i \equiv \kappa_i\theta_i / \sum \kappa_i\theta_i$ is the cost share of the i^{th} media in the advertising budget, and $|B| \equiv 1 + E_{w\tau} + E_{x\tau}$. Once again, a linear restriction across the coefficients in each equation leads to singularity of the covariance matrix and, thus, the tax-rate equation is excluded.

Prior to estimation, a transformation of the data is dictated by the theory of proportional-change. This manipulation expresses each of the time series as first differences in logarithms. That is $\tilde{v}$ is now defined, empirically, as $\tilde{v} \equiv \log(v_t) - \log(v_{t-1})$. One problem arising as a consequence of disaggregation is zeros in the promotion media data. In this case, proportional-adjustments data transformations are feasible only in a subset of the time series. Unfortunately, this subset is very small, implying that degrees-of-freedom becomes a constraining factor. Thus, we shift attention to a difference formulation and demonstrate, in Appendix 3 (available upon request) that the theory remains robust to the difference formulation. In the

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context of equation 16, we redefine $\mathbf{Y} \equiv \mathbf{y}' \equiv (\Delta p, \Delta y, \ldots, \Delta w, \Delta x)'$ and $\mathbf{X} \equiv \mathbf{x}' \equiv (\Delta\theta_1,.., \Delta\theta_K, \Delta z_1,.., \Delta z_{N-2K}, \Delta\kappa_1,.., \Delta\kappa_K)'$, apply the data as first differences (that is, $\Delta v \equiv v_t - v_{t-1}$), and note that the parameters of interest in the reduced-form matrix Ψ are now redefined as follows:

$$\left.\begin{aligned} \pi_{w\theta_i} &\equiv \frac{\kappa_i w_\tau + wxw_{\theta_i}}{|B|} \\ \pi_{x\theta_i} &\equiv \frac{\kappa_i x_\tau + wxx_{\theta_i}}{|B|} \\ \pi_{\tau\theta_i} &\equiv \frac{\kappa_i - \tau xw_{\theta_i} - \tau wx_{\theta_i}}{|B|} \end{aligned}\right\}, \quad i = 1, 2..K, \tag{28}$$

where, in view of the change in the definition of B, the determinant is $|B| \equiv wx + \tau wx_\tau + \tau xw_\tau$. In Appendix 3 we show that, when the null hypothesis is true, the first and second sets of coefficients are zero and the third set equals the tax rate normalized by the level of promotion effort, or τ/θ_i, $i = 1, 2..K$. Once again, an identity between receipts from taxation and program costs forces singularity of the covariance matrix, and, thus, only the price and quantity equations are estimated.

The endogenous variables used in the applications are public reports of auction prices for beef and lamb (cents/kilogram) w_t, $t = 1, 2..T$, and total carcass-weight at market (thousands of tonnes) x_t (Australian Bureau of Agricultural and Resource Economics). Net of the advertising and deflator variables, the remaining instruments are indices of farm-supply and retail-demand shift variables, and indices of two macroeconomic variables assumed to influence non-farm input costs in marketing — the nominal wage and the consumer price index. Because trade in red meats is an important determinant of prices in domestic markets, sets of demand-shift variables relevant to the principal export markets are included. Principal terminal markets for Australian export lamb are the United States and for export beef are the United States and Japan. To better motivate the choice of exogenous variables, a structural trade model of these international markets is constructed. It is presented in Appendix 4 (available upon request). There, several ancillary issues are investigated, including the structural determinants of the investment rule — equation 12 — and the significance of trade and marketing activities in determining the optimal tax rate.

Another question arising in relation to these computations is the endogeneity-cum-exogeneity of the tax rate. As noted above, the tax rate for AMLC funds is set independently from the tax rate required to raise funds for the R&D and policy agencies and, while the rate does not change frequently, it does change often in response to changes in the economic environment. The case of an exogenous tax rate is problematic; in short, the

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analysis, the theory underlying the estimating equations, indeed, the entire investigation is degenerate. To observe this formally, note that, with τ exogenous, Problem 1 (equation 4) is now defined with reference to a single control, θ; but the equality constraint (equation 5) now defines a unique solution $\theta^* = \theta(\tau)$; and, thus, Problem 2 (equation 6) is degenerate.[9] Moreover, in the solution to Problem 2, the derivative τ_θ in equation 7 is now undefined. Instead, one should consider the derivative, θ_τ, and ask how the (unique) value of promotion effort varies in response to the tax rate and, of course, whether τ, in this regression, can be suitably interpreted as exogenous. This discussion motivates employment of a Hausman test in the regression;

$$\Delta\theta_t = \beta\Delta\tau_t + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma), \quad t = 1, 2..T, \tag{29}$$

but a problem prevents application. This is the selection of appropriate instruments under the alternative hypothesis that the tax rate is exogenous. But, since the implicit rate is, by definition (lemma 3), $\tau = \kappa\theta/wx$, the tax rate is surely endogenous.

Another issue arising in this context is the existence of a Laffer-curve effect. Because the tax rate required to fund the program may not be unique, we ask whether the lesser of (possibly) two rates is levied. In this case, evidence of a negative relationship between tax rates and program revenues suggests that the larger of two rates is levied, in which case, inefficiencies in tax collection exist; conversely in the other situation. In order to shed light on this issue two sequences of ad-valorem rates, τ_t, $t = 1, 2..T$, arise from the imputation:

$$\tau_t = \frac{R_t}{w_t x_t}, \quad t = 1, 2..T, \tag{30}$$

applied, respectively, to the beef and lamb sectors; and correlations between revenues and the tax rates are computed. The point estimates for beef and

[9] The same is true, of course, if, instead of assuming that τ is endogenous, we consider that the tax rate must be kept below some maximum level. That is, if, in addition to constraint equation 5, we append to Problem 1 the condition $\tau \leq \bar{\tau}$. When this constraint binds, the tax rate is fixed and is, therefore by definition, endogenous. This situation may be relevant, because, to paraphrase Nerlove and Waugh (1961, p. 820, paragraph 3) and reiterate the view of a referee: 'Since payments must generally be approved by a majority of producers, rates must be kept low enough to continue to attract majority support. Any purely economic theory of cooperative advertising can thus only set an upper bound to optimal expenditures.' While this is true, in general, of most schemes in North-America, and is also the case in the present context, it is impossible to evaluate *a priori*, the impacts of farm aversion toward a higher levy. Such a situation could be modelled although it would require a political preference formulation, which lies considerably outside the scope of the present normative inquiry.

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lamb are strongly positive (at 0.62 and 0.69, respectively). Thus, prior to examining the question of efficient disbursement of funds, we conclude that there is evidence, at least, of efficient taxation.[10]

In both the sheep and beef applications a separable, two-stage demand system is postulated, whereby retail demand varies in response to the prices of other meats and to total meat expenditures; in the beef application the other meats are lamb, pork and chicken; and in the lamb application the other meats are beef, pork and chicken. The price and expenditure series are public reports (Australian Bureau of Agricultural and Resource Economics) employed in Piggott *et al.* (1996) and made available electronically. Detailed reports of non-farm input costs in marketing are unavailable. Consequently, the (nominal) adult weekly wage rate in the retailing sector is used as a proxy for processing costs. Predicated on the basis of capital accumulation in the breeding herd, lagged adjustments in supply are assumed to exist. Specifically, supplies are assumed to respond to period lags in prices and the breeding stock. In the beef application, inventories of cows and heifers from milk and meat cattle are used to construct the stock and in the lamb application, use is made of an index of the numbers of ewes mated to Corridale and Polworth, Long Wool, Merino, and Short Wool rams.

Finally, in an effort to pick up dynamic responses to the promotion media, we consider a distributed lag specification, such that the actual impact in the terminal market of promotion media i at time t, say Θ_{it}, evolves as follows:

$$\Theta_{it} = \sum_{j=0}^{\ell_i} \vartheta_{ij}\theta_{it-j}, \quad i = 1, 2..K, \quad t = 1, 2..T, \tag{31}$$

where the length of the maximum lag, ℓ_i, and the weights, $\vartheta_{ij}, j = 1, 2..\ell_i$, are unknown. We adopt four-quarter lags as the specification of carry-over due to previous work (Kinnucan, Chang and Venkateswaran, 1993) suggesting that this length of frame is likely to be appropriate for generic programs like the present one. With these lags in place — that is, with θ_{it} above equation 23 now replaced with Θ_{it} as in equation 31 — and the data in differences, the parameter restrictions in equation 28 now extend to the coefficients of each of the lagged promotion variables. That is, each coefficient is zero under the null hypothesis of program efficiency. Our main interest lies in the outcome of these tests in the beef and sheep-meat applications that follow.

[10] One valid point in this regard, is the observation made by a referee that political constraints imposed by majority rule would tend to bias the tax rate toward the origin making the presence of Laffer effects unlikely.

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5. Empirical results

Space limitations prohibit a complete presentation of statistical results for each of the beef-price, beef-quantity, lamb-price and lamb-quantity equations. A detailed description of the data series and their sources are presented in Appendix 5 (available upon request).

In time series estimation of vertical marketing systems where significant proportions of the product are traded on international markets, three issues arise that generate considerable scope for statistical evaluation. One is the presence of autocorrelation in the time series; a second is the presence of cross-commodity simultaneity in the vertical marketing system; the third is the possibility for small-country effects in international price determination. We consider each issue in turn, in this order. Table 1 summarises the test results and presents estimates and standard errors of the coefficients in the preferred specifications.

Because time series are the basis for investigation, correlation among the errors is a concern. Box-Pierce autocorrelation statistics are computed in order to gauge the significance of autocorrelation. This statistic is chosen because it is not subject to the usual bias imparted by the presence of lagged dependent variables. Section 1 of table 1 reports results of the tests applied to one-, two-, three- and four-period lagged correlations in the errors. Compared to the critical values of the chi-squared statistics (to the left of the table entries) the tests fail to reject the null hypothesis of independence at the 5 per cent significance level in all but one of the four equations and the four cases; there is slight evidence of second-order correlation in the lamb-price equation. Hence, for the most part, autocorrelation does not appear to be a significant problem in the time series.

The issue of appropriate trade formulation is, perhaps, more compelling as a guide for market structure because acceptance of the small-country hypothesis completely undermines the investigation. This is due to the fact that, in a small-country setting, prices in the markets in question will be determined solely by conditions in the international commodity market, leaving the promotion program impotent in effecting price change. For this reason, we first consider, as an alternative to the (large-country) null hypothesis implicit in equation 22, the equation

$$\Delta w_t = \beta \Delta \bar{w}_t + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma), \quad t = 1, 2..T, \tag{32}$$

where $\bar{w}$ denotes the international market price that is alleged to determine domestic prices; and we compare the two (non-nested) hypotheses using Davidson and MacKinnon's J-test. Under the alternative hypothesis a data series for the price variable, $\bar{w}$, must be adopted. In the beef application, we consider three variants. The first applies the domestic Japanese price for

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grade I beef; the second applies the US wholesale price for grade I beef; and the third considers both prices as separate regressors in a single regression. In the lamb application, the (east-coast) US price for export lamb is used as the rest-of-world price. The results of the tests are presented in section 2 of table 1. In all but one situation (Australia large; Japan considered rest-of-the-world) the tests suggest conclusively that Australia should not be considered small in the international markets for beef and lamb.

The other hypothesis that we examine prior to analysing advertising effects is the hypothesis that the lamb and beef markets should be considered jointly; in other words, that the determination of retail beef and lamb prices is simultaneous. Piggott *et al.* (1995) show, nicely, the consequences of ignoring this aspect of the problem. Its detection amounts to testing that retail prices of lamb and of beef in the respective reduced-forms for beef and lamb are exogenous. To gauge the significance of these phenomena we apply Hausman tests to each equation. Section 3 of table 1 presents the results of the Hausman tests. In each case, the null hypothesis of exogeneity cannot be refuted at the 5 per cent significance level. Thus, prior to examining other effects, we conclude that large-country, single-sector marketing channels are appropriate specifications of the marketing systems and that independence is a reasonable assumption for the time series.

Turning to evaluate more closely the coefficients of advertising effort, three issues arise. The first is the extent to which media responses can be considered homogeneous; the second is the significance of competing allocations from the Australian Pork Corporation (APC); and the third, is the overall significance (*qua*, inefficiency) of the AMLC expenditures. We discuss each effect, in turn, following a brief summary of the unrestricted, ordinary-least-squares results for each equation. Consistent across each specification, intercepts are excluded; quarterly dummy variables for periods two, three, and four are included;[11] one-quarter lagged adjustments to prices are included; and a series of (Hendry) pre-tests is applied in order to determine the optimal lag structure for the stock variables. In the case of beef a seven-quarter lag in the breeding stock is adopted, whereas for lamb, a four-quarter lag is chosen. In general, the equations fit the data satisfactorily. The goodness-of-fit statistics range from a low of 0.62 (lamb-price equation) to a high of 0.93 (beef-price equation). However, few of the regressors are significant at the 5 per cent significance level. Briefly, for beef, neither the AMLC nor the APC advertising media expenditures are significant. Farm

[11] Seasonal effects are postulated for the structural model (equation 16) prior to displacement; once differenced, the design matrix with four-quarter dummies is singular.

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Table 1 Hypothesis test results and preferred specification estimates

	Equation			
	Beef price	Beef quantity	Lamb price	Lamb quantity
1. Box-Pierce Statistics for Serial Independence				
First-order ($\chi^2_{(1,.95)} = 3.842$)	0.109	0.331	1.771	3.675
Second-order ($\chi^2_{(2,.95)} = 5.992$)	1.977	1.993	6.488	3.908
Third-order ($\chi^2_{(3,.95)} = 7.815$)	2.813	3.929	7.254	5.522
Fourth-order ($\chi^2_{(4,.95)} = 9.488$)	5.981	3.393	7.264	5.523
2. T Statistics for International Trade Structure				
Aust. large; Jap. ROW ($t_{(15,.975)} = 2.132$)	2.185			
Aust. small; Jap. ROW ($t_{(68,.975)} = 1.994$)	32.978			
Aust. large; US. ROW ($t_{(15,.975)} = 2.132$)	−0.005		−1.021	
Aust. small; US. ROW ($t_{(68,.975)} = 1.994$)	26.482		22.214	
Aust. large; Jap.-US. ROW ($t_{(15,.975)} = 2.132$)	0.232			
Aust. small; Jap.-US. ROW ($t_{(65,.975)} = 1.994$)	27.355			
3. Chi-Squared Statistics for Exogeneity				
($\chi^2_{(1,.95)} = 3.842$)	0.287	0.656	0.001	0.002
4. F Statistics for Trade-Variable Significance				
($F_{(8,15,.95)} = 2.641$, $F_{(4,19,.95)} = 2.895$)	0.836	0.729	2.224	0.683
5. F Statistics for CPI and Wage Significance				
($F_{(2,23,.95)} = 3.422$)	1.137	1.515	0.666	2.505
6. F Statistics for APC Homogeneity				
($F_{(10,25,.95)} = 2.237$)	2.210	2.129	1.397	1.070
7. F Statistics for APC significance				
($F_{(3,35,.95)} = 2.874$, $F_{(10,35,.95)} = 2.114$)	3.031	2.433	1.868	0.562
8. F Statistics for AMLC Homogeneity				
($F_{(10,45,.95)} = 2.049$, $F_{(10,50,.95)} = 2.026$)	4.125	5.144	3.547	1.997
9. F Statistics for AMLC Significance				
($F_{(15,35,.95)} = 1.963$, $F_{(15,40,.95)} = 1.925$)	1.957	0.765	0.880	0.755
10. AMLC Efficiency Statistics (std. errors)				
Radio	−0.545	1.513	−1.991	0.116
	(1.098)	(1.469)	(1.769)	(0.732)
Television	(−0.024)	(0.014)	(−0.056)	(−0.006)
	(0.051)	(0.065)	(0.090)	(0.036)
Newspaper	0.034	−0.182	0.156	0.037
	(0.178)	(0.234)	(0.353)	(0.140)
Aggregate	−0.535	1.345	−1.891	0.147
	(1.095)	(1.462)	(1.812)	(0.750)

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Table 1 *Continued*

	Equation			
	Beef price	Beef quantity	Lamb price	Lamb quantity
11. Coefficient Estimates (std. errors)				
APC promotion expenditures ($A 000)	0.006	−0.021		
	(0.022)	(0.024)		
APC promotion expenditures(−1) ($A 000)	0.056	−0.056		
	(0.025)	(0.028)		
APC promotion expenditures(−2) ($A 000)	0.029	−0.016		
	(0.029)	(0.032)		
APC promotion expenditures(−3) ($A 000)	0.024	−0.015		
	(0.026)	(0.028)		
APC promotion expenditures(−4) ($A 000)	0.016	0.007		
	(0.022)	(0.024)		
Radio promotion deflator	1.003	−0.020	−0.871	0.333
	(0.527)	(0.581)	(0.941)	(0.365)
Television promotion deflator	0.389	7.299	3.282	1.265
	(3.513)	(3.874)	(5.765)	(2.237)
Newspaper promotion deflator	2.491	0.389	−1.178	2.697
	(2.195)	(2.420)	(3.663)	(1.422)
Retail price of beef (c/kg)			0.444	−0.081
			(0.147)	(0.057)
Retail price of lamb (c/kg)	0.403	−0.346		
	(0.071)	(0.078)		
Retail price of pork (c/kg)	0.071	−0.227	−0.220	−0.032
	(0.119)	(0.131)	(0.221)	(0.086)
Retail price of chicken (c/kg)	−0.161	0.032	−0.023	0.162
	(0.189)	(0.208)	(0.291)	(0.113)
Total expenditures on meats ($A 000)	−0.469	2.167	−0.112	0.261
	(0.159)	(0.175)	(0.254)	(0.098)
Cows and heifers(−7) (million head)	−13.941	13.225		
	(4.033)	(4.447)		
Ewes(−4) (million head)			−2.980	1.750
			(2.019)	(0.784)
Farm price of beef(−1) (c/kg)	0.244	−0.483		
	(0.107)	(0.118)		
Farm price of lamb(−1) (c/kg)			−0.449	0.083
			(0.119)	(0.046)
Second-quarter dummy	−0.505	−4.052	0.4817	−2.193
	(2.353)	(2.594)	(3.689)	(1.432)
Third-quarter dummy	4.075	−5.896	8.875	1.779
	(2.855)	(3.148)	(4.819)	(1.870)
Fourth-quarter dummy	3.778	−17.806	−5.116	5.169
	(2.409)	(2.656)	(3.567)	(1.384)
12. Summary Statistics				
R-squared	0.658	0.877	0.556	0.617
Regression standard error	8.335	9.190	14.208	5.514
Log (likelihood)	−228.638	−235.183	−266.873	−203.462

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prices respond positively to retail prices of lamb and to quarter lags in the farm price of beef; respond negatively to changes in meat expenditures and to period lags in the level of the breeding stock; and are mostly unresponsive to Japanese and US shift-variables (income, prices of substitute meats, and the exchange rate). Farm quantities respond negatively to retail-prices of lamb and respond positively to the US retail price of pork and quarter-two and quarter-three dummy variables. For lamb, as for beef, neither the AMLC nor the APC advertising media generate significant effects. Farm prices respond positively to quarter-two and quarter-three dummy variables; respond negatively to period lags and to changes in the breeding stock; and are mostly unaffected by US shift variables (income, prices of substitute meats and the exchange rate). Quantities, on the other hand, respond negatively to period lags in farm price and to quarter-two and quarter-four dummy variables.

With such an elongated variable list, it is desirable in the interests of parsimony to rationalise reductions in some of the tangential variables. These are, in our context, the trade and macroeconomic variables. One approach (suggested by a referee) is to aggregate in the manner set by the example in Wohlgenant and Clary (1994); another is to remove them altogether. Pursuing the latter strategy, F tests of significance of these effects are reported in the fourth and fifth sections of table 1. Neither the trade variables nor the macroeconomic variables, as groups, are significant at the 5 per cent level.

Before considering AMLC expenditures, we focus attention on the (competing) allocations made by the Australian Pork Corporation (APC). The tests of homogeneity and joint significance of the various media effects are presented in the sixth and seventh parts of table 1. Consistent across the four equations we cannot reject homogeneity of response to the APC expenditures. Conditional on this result, we find that the aggregate APC expenditures are significant in beef but are insignificant in the lamb sector. Turning, now, to consider AMLC effects, homogeneity of response to the three media is rejected in the beef-price, beef-quantity and lamb-price equations, but is not rejected in the lamb-quantity equation. Therefore, we test significance of the AMLC expenditures based on heterogeneous responses. In none of the four equations — beef price, beef quantity, lamb price, lamb quantity — can the test be rejected. That the observed expenditure levels may be efficient is an intriguing possibility. However, an issue arising in the context of the efficiency evaluation stems from the fact that a set of point null hypotheses of zero are being tested. Compared to the usual situation in which parameter significance is desired, this situation poses interpretative problems for sampling-theory approaches. In particular, we wish to avoid the situation in which program efficiency is falsely attributed

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to the fact that the distribution of the test statistic lies near zero. Three possibilities arise. The first is that the distribution is significantly different from zero. This case suggests that inefficiencies in program allocations are present, and the sign of the corresponding coefficient can be used to indicate whether an under-allocation (positive value) or an over-allocation (negative value) has occurred. In the second case, the parameter is statistically insignificant, but the distribution of the test statistic is sufficiently compacted to argue that the allocation is optimal. The third case, statistical insignificance coupled with a dispersed distribution, is inconclusive. As determined by the familiar *F* test, in none of the four cases are the AMLC expenditure effects significantly different from zero when measured at the 5 per cent significance level. The question arising in this circumstance is the extent of possible departure from the efficient levels of expenditure, and whether inefficiencies — should they exist — be rightfully attributed to the program or should more correctly be attributed to inadequate explanatory power of the regression.

In order to gain some better understanding of the source of insignificance we compute distributions of sums of the lagged media coefficients, conditional on the standard errors of the regressions. Under the assumption that the errors are normally distributed, the distribution of the least-squares estimator is multivariate *t* and the marginal distributions of the measures of interest can be computed from a set of standard formulae for the normal-linear model (Zellner 1971, pp. 380–2). Section ten of table 1 reports results of the efficiency computations. For each media type and the aggregate across each of the three types (radio, television, newspaper) we report mean and the standard deviation of 1000 draws from the relevant distribution.[12] The distributions are highly dispersed. Thus, we conclude that the data are insufficiently informative to make precise conclusions about program efficiency. As to the reasons for this, we consider three possible explanations.

First, there is evidence of price averaging and price levelling in some of the markets relevant to this exercise (Griffith *et al.* 1991; Griffith and Piggott 1994). To the extent that these phenomena may be present but are not modelled, they may impart bias and, otherwise, lower precision in the estimates. Yet the literature on asymmetric farm-to-retail price transmission (e.g. Ward 1982; Kinnucan and Forker 1987) is unclear about the refinements that are necessary to encapsulate these phenomena and, in any case, lie beyond the scope of the current investigation. Second, the data are

[12] The programs used to obtain these draws are written in MATLAB (version 5.0) and consumed approximately thirty seconds of CPU time on a Gateway 2000 desktop running a 233 MHz co-processor. They are available upon request.

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highly aggregated and it remains to be seen whether regional or further media disaggregation would prove beneficial. Obviously, data availability remains a main impediment to extensions in this direction. But a third, more promising explanation lies in the definition of equilibrium. In this article we adopt the traditional view that a single farm-to-retail linkage (Gardner 1975) provides a useful benchmark from which to inaugurate empirical work (Wohlgenant 1989). Although this approach is sanctioned by the outcomes of the Hausman test (see table 1, second part), it has been shown (Thurman 1986) that, under certain circumstances, the power of this test may be questionable. With this knowledge, we consider that empirical extensions aimed at incorporating additional relevant sectors, for example, the ones considered in Piggott *et al.* (1995), perhaps provide the most promising avenue for future empirical work. In these extensions, the theory and procedures presented should provide a useful benchmark from which to include additional, relevant empirical detail.

6. Conclusion

This article develops a theory of the allocation of producer levies earmarked for downstream promotion and applies the methodology to quarterly series (1970:2–1988:4) on red-meats advertising by the Australian Meat and Live-stock Corporation. The theory and econometrics are attractive due to their simplicity. The theory postulates a maximisation problem and the econometrics estimates the necessary condition for optimality. Specifically, robust inferences about program efficiency are contained in the coefficients of changes in promotion effort in regressions on movements in farm price and farm quantity. Empirical evidence of efficient allocations by the AMLC is inconclusive. Nevertheless, while the deeper issue of efficient disbursement of funds remains an open question, there is evidence, at least, of efficient taxation.

Limitations to these conclusions stem from two quarters. The first concerns links between promotion targets and the producers for whom benefits are intended. The second concerns the assumption that the test parameter is fixed across the observations in the sample.

The Australian Meat and Live-stock Corporation program attempted to raise producer profits through promotion spending across a variety of media outlets, some that were national in coverage, and some that were regional. The residual impacts of promotion on revenues and profits in the farm sector depend crucially on the initial impacts of promotion in target markets, and the elasticity of price transmission between target and farm-commodity markets. In this regard, it may be fruitful to take more specific account of the regional aspects of downstream activities. However, such

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an analysis would require a model that is considerably more complex than the present one.

Finally, the assumption that the parameters of interest are fixed across expenditure levels is restrictive. Importantly, this assumption is at odds with the (local uniqueness of the) optimisation hypothesis and the concept of an economic experiment wherein the coefficients in question reflect rates of change in the objective function in response to changes in promotion effort. A more general formulation postulates that this coefficient declines with respect to the level of promotion, which it should as a (necessary and sufficient) first-order condition. Extensions in this direction are complicated. Nevertheless, a procedure for retrieving a sample-varying coefficient estimate has been suggested.[13] It closely resembles the Hildreth-Houck procedure. Work progresses on this topic.

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[13] We are indebted to Jeff Dorfman for this suggestion.

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