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Optimal generic advertising in an imperfectly competitive food industry with variable proportions ☆

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Abstract

This paper determines the impact of food industry market power on farmers' incentives to promote in a situation where funds for promotion are raised through a per-unit assessment on farm output and food industry technology is characterized by variable proportions. Specifically, building on earlier studies by Azzam [Am. J. Agric. Econ. 80 (1998) 76] and Holloway [Am. J. Agric. Econ. 73 (1991) 979], Muth's [Oxford Econ. Papers 16 (1965) 221] model is extended to consider the farm-level impacts of generic advertising when downstream firms possess oligopoly and/or oligopsony power and advertising expenditure is endogenous at the market level. Applying the model to the US beef industry, we find that for plausible parameter values market power reduces farmers' incentives to promote. However, the disincentive is moderated by factor substitution, and effectively vanishes as the factor substitution elasticity approaches the retail demand elasticity. This suggests that the Dorfman–Steiner theorem, suitably modified to account for factor substitution, suffices to indicate optimal advertising intensity in the US beef sector.

JEL classification: L66; Q13; Q17

Keywords: Dorfman–Steiner theorem; Generic advertising; Oligopoly power; Oligopsony power

1. Introduction

Consolidation in food retailing and processing over the past two decades has been dramatic. For example, in the United States the four-firm concentration ratio for beef packing between 1978 and 1994 increased from 0.30 to 0.86 and in 2000 the top six supermarket retailers accounted for 50% of supermarket sales, compared with 32% in 1992 (Sexton, 2000, p. 1087). An issue of growing concern is the implication of this trend for farmers' incentives to invest in generic advertising and other self-help initiatives. Although substantial research has been done to determine the effect of the funding mechanism, trade, export promotion subsidies and policy interventions on promotion incentives (see, e.g. Freebairn and Alston (2001) and the references cited therein), relatively little is known about imperfect competition's effect. The few studies that have been done are empirical in nature (Suzuki et al., 1994), focus on monopoly effects (Goddard and McCutcheon, 1993; Kinnucan and Thomas, 1997; Kinnucan, 1999), or assume that food industry technology is of a fixed proportions or Leontief type (Cranfield and Goddard, 1999; Zhang and Sexton, 2000). No systematic analysis exists to indicate how oligopoly and/or oligopsony power affects promotion

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incentives when food industry technology is characterised by variable proportions.

The latter issue is important because variable proportions appear to hold in the case of the US beef and pork industries (Wohlgenant, 1989; see also Goodwin and Brester, 1995) where concerns about non-competitive pricing are particularly acute. In these instances, a fixed-proportions framework would tend to prejudice the analysis in favour of large advertising budgets. Moreover, as is demonstrated in this study, disallowing input substitution may cause market power effects to be exaggerated. The reason is that market power's affect on the derived demand elasticity for the farm-based input tends to be more pronounced under fixed proportions than under variable proportions. Since the demand elasticity is a key determinant of advertising profitability (Dorfman and Steiner, 1954), it follows that farm-level returns from advertising will be more sensitive to market power when input substitution is disallowed than when it is permitted.

Variable factor proportions is a contested issue in the agricultural economics literature. The controversy is perhaps best summarised by Wohlgenant and Haidacher (1989, p. 8):

> Even though input substitution provides theoretical justification for observed margin behaviour, there is a view in the profession that such substitution possibilities are quite limited, and are restricted to reductions in the amount of waste and spoilage as the price of the farm product rises .... This view of input substitution, however, is too narrow. It ignores the fact that a firm can choose among one or more production processes, or technologies, at any time. For example, fresh produce could be shipped to market by truck, by rail, or by boat .... For each mode of transport, different combinations of marketing services and farm product are available to produce the retail product, and so opportunities for input substitution can arise from switching between transport modes .... Even if all firms employ inputs in fixed proportions, we still should expect to observe input substitutability at the industry level. The reason is that firms, because of differences in firm size, often use different input proportions (through different production processes or activities) to produce similar products.

Sexton (2000, pp. 1089–90), in adopting the fixed proportions framework, admits that it is a simplification, but argues (correctly) that the important point is that the assumption "... must not bias the analysis of competition in any particular direction". Our analysis suggests that in this regard the assumption of fixed proportions is not innocuous.

The purpose of this research is to determine the optimal advertising:sales ratio for a situation in which food industry technology is characterised by variable proportions, middlemen possess market power, and advertising funds are raised through a per-unit assessment on farm output. The analysis is based on a Muth-type model that in essence combines Holloway's (1991) model of oligopoly behaviour with Azzam's (1998) model of oligopsony behaviour. An advantage of this formulation is that a derived 'demand' curve for farm output can be obtained that shows clearly how advertising shifts this curve when the price of marketing services is endogenous. A key result is that market power tends to reduce promotion incentives, but that the attenuation is moderated by factor substitution.

2. Model

Consider an industry that combines a farm-based input a with a bundle of marketing inputs b to produce a retail product x under conditions of constant returns to scale (CRTS). Firms in the industry take the price of marketing services P_b as given, but have sufficient market presence to influence the price of the farm-based input P_a, and the price of the retail product P_x. That is, downstream firms exercise oligopoly power in the x market and oligopsony power in the a market, but are individually too small in relation to the total food economy to influence P_b. Consumer demand for the industry's product is separable from other goods such that substitution effects can be ignored, at least as a first approximation. The farm sector raises A dollars for promotion via a tax of T dollars per unit on farm marketings. Thus, advertising expenditures at the industry level are endogenous and dependent on farm output. The economy is closed and prices are determined without government interference.

With these assumptions initial equilibrium in the channel is defined as follows:

$$x = D(P_x, A) \quad \text{(demand for } x\text{)} \tag{1}$$

$$x = f(a, b) \quad \text{(CRTS production function)} \tag{2}$$

$$P_a(1 + \Omega) = P_x f_a(1 - \Psi) \quad \text{(demand for } a\text{)} \tag{3}$$

$$P_b = P_x f_b(1 - \Psi) \quad \text{(demand for } b\text{)} \tag{4}$$

$$P_a = g(a) + T \quad \text{(supply of } a\text{)} \tag{5}$$

$$P_b = h(b) \quad \text{(supply of } b\text{)} \tag{6}$$

$$A = Ta \quad \text{(advertising budget)} \tag{7}$$

where f_i ($i = a, b$) are a's and b's marginal products; $\Psi = \xi/\eta$ is the Lerner index that denotes oligopoly power, where η is the absolute value of the retail demand elasticity, and $\xi \in [0, 1]$ the output conjectural elasticity ($\xi = 0$ for perfect competition and $\xi = 1$ for pure monopoly); $\Omega = \theta/\varepsilon_a$ is the Lerner index to denote oligopsony power, where ε_a is the supply elasticity for a, and $\theta \in [0, 1]$ the input conjectural elasticity ($\theta = 0$ for perfect competition and $\theta = 1$ for pure monopsony).

The foregoing model is similar to Zhang and Sexton's (2000) in that both oligopsony and oligopoly power are considered within a single framework. However, it is more general in that the assumption of fixed proportions is relaxed, and the price of marketing inputs is treated as endogenous at the industry level. That is, although individual firms in the industry are too small to affect P_b, collectively the firms account for a sufficiently large portion of the total food economy so that industry-wide changes in the demand for b influence P_b. The same distinction applies to A. Specifically, Eqs. (3) and (4) are based on the assumption that advertising expenditure is endogenous at the industry level, but not at the firm level. That is, downstream firms make input choices without regard to the fact that such choices might affect the level of generic advertising. To the extent that this is not true, the model will tend to *understate* optimal advertising expenditure.[1] (The importance of this potential understatement is analysed later.) Eqs. (1)–(6) reduce to Holloway's model when $\Omega = 0$ and to Azzam's (1998) model when $\Psi = 0$. Thus, the present model subsumes these earlier models as special cases.[2]

The model contains seven endogenous variables (P_x, P_a, P_b, x, a, b, and A), one exogenous variable (T), and four parameters (ξ, θ, η, and ε_a). Following the standard assumption for models of this type (see, e.g. Muth, 1965; Gardner, 1975), the parameters are treated as fixed constants. Thus, Ψ and Ω are properly interpreted as exogenous variables. In this sense, our model is less general than Zhang and Sexton's (2000) model in that the latter model permits η to adjust in response to advertising or market-power induced changes in equilibrium quantity. Although endogenising η is a useful refinement, it should not affect results significantly provided equilibrium displacements are small or the retail demand curve is of the constant-elasticity type in the relevant range.[3]

3. The derived 'demand' curve for farm output

The first task is to derive an expression that under certain conditions can properly be interpreted as the derived curve for farm output. For this purpose, and following Muth (1965), we begin by expressing Eqs. (1′)–(7′) in percentage changes as follows:

$$x^* = -\eta P_x^* + \beta A^* \tag{1′}$$

$$x^* = \kappa_a' a^* + (1 - \kappa_a')b^* \tag{2′}$$

[1] I thank Richard Sexton and Mingzia Zhang for pointing out this model limitation. As shown in an appendix available from the author, firm-level endogeneity requires that Eq. (3) be replaced with $P_x f_a(1 - \Psi) = P_a(1 + \Omega - \Phi)$ where $\Phi = \beta\Psi/S_a$ is an advertising 'feedback' term. Since this term is vanishingly small in the present analysis, it can be safely ignored.

[2] Technically, the present model reduces to Azzam's (1998) model when open-market and captive supplies in the latter model are perfect substitutes. In verifying this reduction, I discovered an error in Azzam's model that was graciously confirmed by the author. Specifically, referring to p. 78, Eq. (13) of Azzam's paper, the $(1+\Omega)$ term that multiples $\hat{a}$'s coefficient is errant and should be deleted. In addition, there appears to be an error (probably typographic) in Holloway's model, which, if not corrected, will frustrate attempts to reduce Eqs. (1)–(6) to that model. In particular, Holloway (1991, p. 983) defines the value-share terms as $\omega_i = S_i(\theta+\eta)/\eta$, where $i = a, b$. As shown in Appendix A, the correct definition is $\omega_i = S_i\eta/(\theta + \eta)$.

[3] Although equilibrium displacements associated with generic advertising are typically small (since the advertising elasticities are generally minute), this may not be the case for market power. However, in the latter case there is a mitigating factor in that a market-power induced increase in η will tend to have opposing effects on optimal advertising intensity (as shown later), and thus may be largely self-canceling.

$$P_a^* = -\left[\frac{(1-\kappa_a')}{\sigma}\right]a^* + \left[\frac{(1-\kappa_a')}{\sigma}\right]b^* + P_x^* - \eta_\Psi\Psi^* - \varepsilon_\Omega\Omega^* \quad (3')$$

$$P_b^* = \left(\frac{\kappa_a'}{\sigma}\right)a^* - \left(\frac{\kappa_a'}{\sigma}\right)b^* + P_x^* - \eta_\Psi\Psi^* \quad (4')$$

$$P_a^* = \left(\frac{1}{\varepsilon_a}\right)a^* + \tau T^* \quad (5')$$

$$P_b^* = \left(\frac{1}{\varepsilon_b}\right)b^* \quad (6')$$

$$A^* = T^* + a^* \quad (7')$$

where the asterisked variables indicate relative change (e.g. $x^* = \mathrm{d}x/x$); β is the advertising elasticity; $\kappa_a' = S_a(1+\Omega)/(1-\Psi)$ the factor a's cost share inclusive of oligopsony and oligopoly rent (see Appendix A), hereafter referred to as the 'value-share' term;[4] σ the Hicks–Allen factor substitution elasticity; $\eta_\Psi = \Psi/(1-\Psi)$ and $\varepsilon_\Omega = \Omega/(1+\Omega)$ are elasticities that indicate the percent vertical shift in input demand curves (3) and (4) per 1% change in the respective market power indices holding output prices constant; $\tau = T/P_a$ is the advertising tax expressed as a fraction 'of the initial equilibrium farm price'; and ε_b is the supply elasticity for marketing services.

In this study, all parameters are assumed to be positive, i.e. retail demand is downward sloping ($-\eta < 0$); advertising shifts the retail demand curve to the right ($\beta > 0$); the input supply curves are upward-sloping ($\varepsilon_a > 0$ and $\varepsilon_b > 0$); and food industry technology exhibits variable proportions ($\sigma > 0$). Importantly, the farm-share term $S_a = P_a a/P_x x$ is evaluated 'at the initial equilibrium point' (see Appendix B); thus, the value-share term κ_a' in Eqs. (2′)–(4′) is properly interpreted as a fixed constant, as is τ in Eq. (5′).

The derived 'demand' curve for farm output is obtained by dropping Eqs. (5′) and (7′) (since we want to treat farm price and advertising expenditures as temporarily exogenous) and solving the remaining equations simultaneously for a^* to yield:

$$a^* = -\left[\frac{(\varepsilon_b\lambda' + \eta\sigma)}{D}\right]P_a^* + \left[\frac{\beta(\varepsilon_b+\sigma)}{D}\right]A^* - \left[\frac{\eta_\Psi\eta(\varepsilon_b+\sigma)}{D}\right]\Psi^* - \left[\frac{\varepsilon_\Omega(\varepsilon_b\lambda + \eta\sigma)}{D}\right]\Omega^* \quad (8)$$

where $\lambda' = (\kappa_a'\eta + (1-\kappa_a')\sigma) > 0)$ and $D = (\varepsilon_b + \kappa_a'\sigma + (1-\kappa_a')\eta) > 0$. Since P_a^*'s coefficient is negative under the stated assumptions, the derived 'demand' curve is downward sloping, as might be expected. Also, A^*'s coefficient is positive and Ψ^*'s coefficient is negative, which means that simultaneous increases in advertising and oligopoly power shift the derived 'demand' curve in opposite directions. This, too, is in accordance with economic logic.

If P_b is exogenous, as is assumed by Zhang and Sexton (2000) and Wohlgenant (1993), Eq. (8) reduces to:

$$a^* = -\lambda' P_a^* + \beta A^* - \eta_\Psi\eta\Psi^* - \varepsilon_\Omega\lambda\Omega^*\cdot \quad (8a)$$

In this case, P_a^*'s coefficient is simply $-\lambda'$, which is equivalent to Waterson's expression for the market elasticity of derived demand when $\Omega = 0$, and to Allen's expression when $\Psi = \Omega = 0$ (see, e.g. Bronfenbrenner, 1961, p. 259). Thus, in these instances Eqs. (8) and (8a) may be interpreted as the derived demand curve for farm output without qualification. In instances where $\Omega > 0$ the derived demand curve collapses to a single point when $\theta = 1$ (pure monopsony), and thus the curve is ill-defined. Nonetheless, henceforth we will ignore this technicality, since no harm is done provided this qualification is borne in mind (see, e.g. Friedman, 1976, p. 190). As previous analysis suggests that treating P_b as exogenous has no important effect on promotion incentives (Kinnucan, 1997), the remaining analysis will focus on Eq. (8a) unless indicated otherwise.

3.1. Interpretation of coefficients

Ψ^*'s coefficient in Eqs. (8a) and (8) is equal and opposite in sign to A^*'s coefficient when $\eta_\Psi = \beta/\eta$. This implies that generic advertising's ability to offset the negative effects of oligopoly power on farm-level demand hinges on the β/η ratio. What is interesting about this result is that β/η is equivalent to Dorfman

[4] The term 'value share' is suggested by Waterson (1980) who derived an expression for the derived demand elasticity under oligopoly using duality theory.

and Steiner's (D–S) rule (1954) for optimal advertising. Specifically, the D–S theorem states $\bar{\phi} = \beta/\eta$, where $\bar{\phi}$ is the optimal advertising intensity (advertising expenditure divided by industry revenue) for a monopoly with fixed output. Alston et al. (1994) [hereafter ACC] show that the same condition applies to a competitive industry that raises funds for promotion through a per-unit tax. Since generic advertising intensities for agricultural products are generally <0.06 (ACC, 1994, p. 161, Table 1) it may be inferred from Eq. (8a) that an increase in oligopoly power (as measured by the Lerner index) in general will have a larger (negative) effect on farm-level demand than an equivalent percentage increase in advertising expenditure.

Turning to oligopsony power, Ω^*'s coefficient in Eq. (8a) is proportional to the derived demand elasticity (P_a^*'s coefficient). This implies that factors that make retail demand more (less) price elastic tend to magnify (attenuate) oligopsony power's effect at the farm level. Stated differently, as farm supply becomes less elastic in relation to retail demand, the farm-level impact of the oligopsony distortion is accentuated. Thus, for example, in Zhang and Sexton's (2000) simulation work where the retail demand curve is linear, η increases *pari passu* with increases in oligopsony power (since equilibrium quantity is reduced). In this case, a larger reduction in the 'demand' for farm output would occur than would be true if the retail demand curve were of the constant elasticity type (as is implicitly assumed here).

Table 1
Baseline values and parameters for US beef industry, 1998

Item	Definition	Value
P_x	Retail beef price (\$/lb.)	2.77[a]
x	Retail beef quantity (million lbs.)	18412[a]
S_a	Farmers' cost–share	0.472[a]
v	Farm value (million US\$ ($= S_aP_xx$))	24073
A	Generic advertising expenditure (million US\$)	28.3[b]
φ_R	Advertising intensity ($= A/P_xx$)	0.00056
β	Advertising elasticity	0.0005[c] or 0.0011[d]
η	Retail demand elasticity (absolute value)	0.42[d], 0.56[e], or 0.78[f]
σ	Factor substitution elasticity	0, 0.25, 0.50, or 0.72[f]
ε_a	Farm supply elasticity	0.15[f]
ε_b	Marketing services supply elasticity	1.00, 2.00[g], or ∞[f]
ξ	Output conjectural elasticity	0–0.10[h]
θ	Input conjectural elasticity	0–0.10[h]

[a] USDA, ERS (2001).
[b] National Cattleman's Beef Association.
[c] 'Best-bet' value, see text.
[d] Kinnucan et al., 1997.
[e] Brester and Schroeder, 1995.
[f] Wohlgenant, 1993.
[g] Gardner's (1975) most frequent value.
[h] 'Best-bet' upper limits, see text.

What of oligopsony and oligopoly's power relative impact? To answer this, let $\Psi = \Omega = 0.18$ so that the distortions are equivalent. In this case, $\varepsilon_\Omega = \Omega/(1 + \Omega) = 0.15$, which is less than $\eta_\Psi = 0.22$. This implies from Eq. (8a) that under the stated assumptions oligopoly power always has a *larger* effect on farm-level 'demand' than comparable oligopsony power, provided $\eta \geq \lambda'$ (sufficient condition). The latter condition always holds when $\eta \geq \sigma$, as appears to be true for the beef, pork, and poultry industries in the United States (Wohlgenant, 1989, p. 250).

Returning to the advertising effect, A^*'s coefficient in Eq. (8a) is simply the advertising elasticity β. This means that if P_b is indeed exogenous, as is commonly assumed, then the advertising-induced demand shift at the farm level is identical to the shift at the retail level. However, if P_b is endogenous, the demand shifts at the two market levels in general are not identical. In particular, letting $E_{a,A} = \beta(\varepsilon_b + \sigma)/D$, A^*'s coefficient in Eq. (8), it can be shown that $E_{a,A} = \beta$ only in the special case where $\eta = \sigma$. For US meats, where $\eta > \sigma$, we have $E_{a,A} < \beta$, which means the advertising elasticity *overstates* the farm-level demand shift when P_b is endogenous, as might be expected because then there is price rationing in the b market.

3.2. Market power and the derived demand elasticity

As alluded to in connection with the D–S theorem, an industry's incentive to promote is inversely related to the absolute value of the demand elasticity. Thus, it is of some interest to know how food industry market power might affect the derived demand elasticity for farm output, as this parameter is pivotal in determining farmers' incentive to invest in demand-strengthening activities.

To determine that, consider the following expressions for the derived demand elasticity:

$$\lambda' = \kappa'_a\eta + (1 - \kappa'_a)\sigma\cdot \tag{9a}$$

$$\lambda = S_a\eta + (1 - S_a)\sigma\cdot \tag{9b}$$

Where λ' is derived demand elasticity under imperfect competition when P_b is exogenous (see Eq. (8a)) and λ the corresponding expression under perfect competition (see, e.g. Bronfenbrenner, 1961). Intuitively, for imperfect competition to reduce farmers' incentive to promote, as suggested by Zhang and Sexton's (2000) analysis, one would expect that $\lambda' > \lambda$. To check this, we subtracted Eq. (9b) from Eq. (9a) as follows:

$$\lambda' - \lambda = \left[\frac{S_a(1 + \Omega)}{(1 - \Psi)}\right](\eta - \sigma)\cdot \tag{9c}$$

Since the term in square brackets in Eq. (9c) is always positive for permissible parameter values, intuition is confirmed, *provided* $\eta > \sigma$. Indeed, in Zhang and Sexton's (2000) analysis $\sigma = 0$, so this condition is satisfied. That is, in a fixed-proportions framework food industry market power in effect makes farm-level demand more price elastic, which makes advertising less profitable from the farmer's perspective.

In a variable proportions framework Eq. (9c) may be positive or negative depending upon whether consumers can substitute more easily than middlemen. If $\eta > \sigma$, which implies that a and b are gross complements (see, e.g. Alston and Scobie, 1983), an increase in either oligopoly or oligopsony power always reduces the incentive to promote. The opposite obtains if $\eta < \sigma$, meaning that a and b are gross substitutes. Since Wohlgenant (1989, p. 250) finds that $\eta < \sigma$ for eggs, fresh vegetables and dairy, the finding that market power may *enhance* farmers' incentive to promote when a and b are gross substitutes is more than a theoretical curiosity. In particular, it suggests that factor substitution may play an important role in moderating market power's effect on promotion incentives, an issue to be addressed in detail later.[5]

[5] A caveat in interpreting Eq. (9c) is that it is based on the implicit assumption that S_a in Eqs. (9a) and (9b) has identical values, i.e. market power does not affect the farmers' cost share. Relaxing this assumption complicates the analysis, but does not alter the basic idea that market power's effect on the derived demand elasticity is ambiguous when $\sigma > 0$. The reason is related to Marshall's third law of derived demand as discussed by Bronfenbrenner (1961, pp. 256f).

3.3. *Effects of a change in η on derived demand*

Quilkey (1986) argues *inter alia* that generic advertising's main effect is to alter the demand elasticities (price and income) for the goods in question. Thus, it is of some interest to know how such alterations would affect farm-level demand in the presence of oligopoly power.

To address this issue we first express Eq. (8) in simplified notation as follows:

$$a^* = -E_{a,Pa}P_a^* + E_{a,A}A^* - E_{a,\Psi}\Psi^* - E_{a,\Omega}\Omega^*, \tag{8'}$$

where $E_{a,Pa}$, $E_{a,\Psi}$ and $E_{a,\Omega}$ are short-hand expressions for the corresponding coefficients given in Eq. (8) expressed as absolute values. Then, taking advantage of the fact that $\Psi^* = \xi^* - \eta^*$ and setting $\Omega = 0$ (to focus attention on oligopoly power), the above equation may be written equivalently as:

$$a^* = -E_{a,Pa}P_a^* + E_{a,A}A^* - E_{a,\Psi}(\xi^* - \eta^*)\cdot \tag{8''}$$

From Eq. (8″), an increase in the retail demand elasticity has an effect on farm-level demand that is both equal and opposite to an increase in the output conjectural elasticity.

This implies that an advertising campaign designed to make retail demand less price elastic may be counterproductive in the presence of oligopoly power in that it would tend to reduce demand at the farm level. However, there is a countervailing effect in that a decrease in η decreases λ', *ceteris paribus*, which, in turn, increases the incentive to promote (by the D–S theorem). The upshot is that downstream oligopoly power renders η's effect on promotion incentives at the farm level uncertain.

4. Optimal advertising tax and intensity

The analysis thus far has considered the relationship between market power and promotion incentives by focusing on a's quasi-reduced form. To sharpen these results, we now develop an expression for the optimal tax rate, i.e. the rate that maximises producer surplus when the revenue generated by the tax is spent on generic advertising. Conveniently, the expression that defines the optimal tax rate also defines the optimal advertising intensity. Thus, analysis of the expression for the optimal tax *rate* (per-unit levy divided by farm price) also provides information about the optimal advertising intensity.

To derive the optimality condition, we first need to know how a simultaneous increase in the tax and advertising expenditure will affect demand at the farm level when price effects are taken into account. For this purpose, we substitute Eq. (5′) and (7′) into Eq. (8′) to obtain the reduced-form equation for farm quantity:

$$a^* = \left[\frac{\varepsilon_a(E_{a,A} - \tau E_{a,Pa})}{D'}\right] T^* - \left[\frac{\varepsilon_a E_{a,\Psi}}{D'}\right] \Psi^* - \left[\frac{\varepsilon_a E_{a,\Omega}}{D'}\right] \Phi^* \quad (10)$$

where $D' = (\varepsilon_a(1 - E_{a,A}) + E_{a,Pa})$. Eq. (10) indicates the *net* effects of changes in the exogenous variables on equilibrium farm output, i.e. the effects that take into account induced changes in farm price and advertising expenditure. Under the maintained hypothesis that $D' > 0$, the coefficients of Ψ^* and Ω^* in Eq. (10) have the same signs as the corresponding coefficients in Eq. (8). This means that endogenising farm price and advertising expenditure affects the magnitude, but not the direction, of the market power effects.

T^*'s coefficient in Eq. (10) is key from the standpoint of optimising behaviour. This coefficient, which is properly interpreted as a reduced-form elasticity, has an uncertain sign. The reason is that the coefficient represents the net effect on equilibrium farm quantity of a simultaneous shift in supply and demand, with the curves shifting in opposite directions. Thus, the critical question is whether the demand shift induced by the advertising expenditure exceeds the supply shift induced by the tax. With this in mind, the optimal tax rate can be derived from Eq. (10) by invoking the condition developed by Alston et al. (1994, p. 157), which states:

> The check-off advertising tax will be optimised when an increase in the check-off yields an additional vertical shift in demand of the same amount per unit so that, at the margin, the combined advertising and check-off will have no net effect on quantity and $\partial q/\partial t = 0$.

To apply this condition, we set $\Psi^* = \Omega^* = 0$ (since we want to isolate the tax effect), and solve Eq. (10) for τ when $a^*/T^* = 0$ to obtain:

$$\bar{\tau} = \frac{E_{a,A}}{E_{a,Pa}}$$

where $\bar{\tau}$ is the tax rate ($\bar{\tau} = \bar{T}/P_a^{\text{o}}$) that maximises producer surplus when the tax proceeds are invested in promotion. Substituting the parameter values from Eq. (8) into the above relation yields:

$$\bar{\tau} = \frac{\beta(\varepsilon_b + \sigma)}{(\varepsilon_b\lambda' + \eta\sigma)}. \quad (11)$$

From Eq. (11) the optimal tax rate is directly related to the advertising elasticity β, and inversely related to the retail and derived-demand elasticities η and λ', as might be expected based on the D–S theorem.

That Eq. (11) is equivalent to optimal intensity can be seen by noting that:

$$\bar{\tau} = \bar{\tau}\frac{a}{a} = \bar{T}\frac{a}{(P_a a)} = \frac{\bar{A}}{(P_a a)} = \bar{\phi}_F$$

where $\bar{A}$ is the optimal advertising expenditure in imperfectly competitive equilibrium, and $\bar{\phi}_F$ is the optimal advertising intensity defined in terms of *farm* value. Since optimal intensity and optimal tax rate are synonymous, we will henceforth refer to Eq. (11) as optimal intensity.

Importantly, Eq. (11) generalises the D–S theorem (and thus ACC's result) in that it takes into account the marketing channel. In addition, it is more general than Zhang and Sexton's (2000) condition (p. 12, Eq. (15′)) in that it permits factor substitution and does not require that P_b be exogenous. However, as noted Eq. (11) assumes that η is a fixed constant and does not account for the advertising feedback effect. The relative importance of these restrictions can be determined by considering Eq. (11)'s analogue when P_b is exogenous:

$$\bar{\phi}'_F = \frac{\beta}{\lambda'} = \frac{(1-\Psi)\beta}{[S_a(1+\Omega)\eta + S_b\sigma]}$$

where $S_b = 1 - \Psi - S_a(1+\Omega)$ is factor b's rent-exclusive cost share (see Appendix A). Multiplying this expression through by $(P_a a)/(P_x x)$ yields:

$$\bar{\phi}'_R = \frac{(1-\Psi)\beta}{[(1+\Omega)\eta + \omega\sigma]} \quad (12)$$

where $\bar{\phi}'_R\bar{A}/(P_x x)$ is the optimal intensity expressed in terms of *retail* value and $\omega = S_b/S_a$ is the cost–share ratio.

By way of comparison, Zhang and Sexton's condition (2000, p. 13) for fixed η in our notation is:

$$\bar{\phi}_R^{\mathrm{ZS}} = \frac{(1-\Psi+\Psi\beta)\beta}{\eta}. \tag{13}$$

Comparing Eqs. (12) and (13) and setting $\Omega = 0$ we see that Eq. (12) understates the optimal intensity under fixed proportions, since the feedback term $\Psi\beta$ in Eq. (13) is positive in sign. However, since $\Psi < 1$ and β is generally <0.05 (see, e.g. Ferrero et al., 1996) the degree of understatement is in most cases negligible.

Since market power reduces equilibrium quantity, η in general is expected to increase with increases in market power unless the retail demand curve is a rectangular hyperbola in the relevant range. Thus, it is of some interest to know how such changes would affect optimal intensity. Since results are qualitatively similar for Eqs. (12) and (13), we focus on the simpler expression Eq. (13), which yields the following derivative:

$$\frac{\partial\bar{\phi}_R^{\mathrm{ZS}}}{\partial\eta} = \frac{\beta[2\Psi(1-\beta)-1]}{\eta^2}.$$

From this expression η's effect is uncertain. In particular, the inverse relationship between optimal intensity and η indicated by the D–S theorem holds only if oligopoly power is sufficiently weak such that $\Psi < 1/[2(1-\beta)]$. The reason is that an increase in η has two opposing effects: it benefits producers by attenuating the oligopoly distortion, but is also harms producers by weakening advertising's price effect. The upshot is that, owing to the offsetting effects, treating η as a constant should be relatively innocuous when evaluating promotion incentives.

Returning to Eq. (12), under fixed proportions ($\sigma = 0$) an increase in either oligopoly or oligopsony power always reduces optimal intensity, which is consistent with Zhang and Sexton's analysis. This simple relationship, however, no longer holds under variable proportions. The reason is that the cost–share ratio ω comes into play when $\sigma > 0$, and this ratio may either increase or decrease with changes in market power.[6] Specifically, letting $\zeta = (1+\Omega)\,\eta + \omega\sigma$ and taking the partial derivative of Eq. (12) with respect to the Lerner indices yields:

$$\frac{\partial\bar{\phi}'_R}{\partial\Psi} = \frac{\beta[\zeta+\sigma(1-\Psi)(\partial\omega/\partial\Psi)]}{\zeta^2},$$

$$\frac{\partial\bar{\phi}'_R}{\partial\Omega} = \frac{-\beta(1-\Psi)[\eta+\sigma(\partial\omega/\partial\Omega)]}{\zeta^2}.$$

From these expressions, an increase in market power has an unambiguously negative effect on promotion incentives only if $\partial\omega/\partial\Psi$ and $\partial\omega/\partial\Omega$ are positive. In the present analysis, where these derivatives are negative (since S_a is held constant at its initial equilibrium level), the effect is uncertain.

That factor substitution plays an important role in promotion incentives can perhaps be best appreciated by noting that when $\Omega = \Psi = 0$ condition Eq. (12) reduces to:

$$\bar{\phi}_R^{\mathrm{DS}} = \frac{\beta}{[\eta+(1-S_a)/S_a)\sigma]} \tag{14}$$

where $\bar{\phi}_R^{\mathrm{DS}}$ is hereafter called the 'modified D–S theorem'. In particular, Eq. (14) defines the optimal advertising intensity in competitive equilibrium when P_b is exogenous and marketing technology is characterised by variable proportions. Since for most farm products $\eta < 1$, $(1-S_a)/S_a > 1$ (USDA, ERS (2001)), and $0.25 < \sigma < 1$ (Wohlgenant, 1989), Eq. (14) suggests that even modest departures from fixed proportions could significantly weaken farmers' incentive to promote. Whether such departures are important in determining promotion incentives in the presence of imperfect competition is an empirical issue to which we now turn.

5. Application to US beef industry

To demonstrate the model's empirical utility, and to gain further insight into the importance of factor

[6] The intuition here is that under variable proportions the derived demand elasticity for farm output is a cost-share weighted average of the retail demand and input substitution elasticities (see Eqs. (9a) and (9b)). Thus, a market power induced change in cost shares may either increase or decrease λ' depending on the relative magnitudes of η and σ.

substitution, we apply Eq. (11) to the US beef industry using parameter values as indicated in Table 1. The beef industry is a useful case study because its promotion program is the third largest in the United States (after dairy and citrus, see Forker and Ward, 1993, pp. 102–103), the four-firm concentration ratio is high (above 0.86), and considerable research has been done to estimate market power and related parameters. Moreover, the model's assumptions (variable proportions, constant returns to scale and a closed economy) are approximated in this instance (Wohlgenant, 1989, 1993).[7] In 1998, the base year for our analysis, the industry invested US$ 28.3 million (mUS$) in generic advertising. The retail value of beef in that year was US$ 50.8 billion (bUS$), which yields an observed advertising intensity of 0.056%. At issue, whether this intensity is too high or low, and what is the effect of market power on the optimal intensity in the presence of factor substitution.

5.1. Parameterisation

Since η and σ critically influence market power's effect on promotion incentives, we consider a range of values for these parameters. Specifically, η is set alternatively to 0.78, 0.56 and 0.42; 0.78 is the value used by Wohlgenant (1993); the latter two values were estimated, respectively, by Brester and Schroeder (1995), and Kinnucan et al. (1997) (see Table 1). For σ we used selected values ranging from 0 to 0.72, Wohlgenant's (1989, p. 250) estimate of this parameter. We choose 0.72 as σ's upper limit to address Sexton's concern (2000, p. 1095, fn. 14) that empirical estimates of factor substitution elasticities may be overstated due to the use of highly aggregated data.

Despite the attention given to estimating market power parameters for US beef, the estimates remain controversial. For example, Muth and Wohlgenant (1999) reject the hypothesis of market power, while Azzam and Schroeter (1995) find at least a mild degree of price exploitation. In his study of captive beef supplies, Azzam (1998) uses 0.06 as an upper-limit value for θ, and seems to prefer a value of 0.03 for this parameter. Based on this, and Sexton's (2000) view that empirical estimates of market power parameters are probably understated, we set $\theta \leq 0.10$. As for oligopoly power, the empirical literature suggests that oligopoly power in the beef marketing channel is probably less than oligopsony power, especially when successive oligopsony is considered (Schroeter et al., 2000). Thus, in this study we assume that $\xi \leq \theta$.

Perhaps as controversial is the generic advertising elasticity for beef. Some studies find β to be positive and statistically significant (Ward and Lambert, 1993), while others find the parameter to be insignificant or fragile (Brester and Schroeder, 1995; Kinnucan et al., 1997). In an attempt to reconcile these findings, Coulibaly and Brorsen (1999) found that results are sensitive to model specification, lag structures, and data sources. With this in mind, we use $\beta = 0.0005$ as a 'best-bet' value, since it is in line with estimates obtained in Coulibaly and Brorsen's (1999) study. However, to test the sensitivity of results to this parameter, we conduct an additional simulation with $\beta = 0.0011$, Kinnucan et al.'s (1997) most optimistic point estimate.

The farm supply elasticity is set to $\varepsilon_a = 0.15$, the value used in Wohlgenant's (1993) study. Since this elasticity plays a limited role in the optimality condition, and its value is relatively non-controversial, no sensitivity analysis is done on this parameter. The marketing services' supply elasticity was assumed to be infinity in Wohlgenant's (1993) study. Here, we set $\varepsilon_b = 2.0$, a value that seems to be preferred by Gardner (1975). However, given the wide range of values used in the literature, we set ε_b alternatively to one and infinity to gauge the sensitivity of results to this parameter. The farm cost–share parameter is set to $S_a = 0.472$, USDA, ERS's (2001) estimate of this parameter for 1998.

5.2. Results

To establish a baseline we set $\theta = 0.05$ to indicate oligopsony power and $\xi = 0.05$ to indicate oligopoly power. Based on these parameter values,

[7] A shortcoming of the present analysis is that it does not take into account demand interrelationships, which are important in the case of beef. One way to handle this deficiency without complicating the model is to re-interpret β and η as 'total' elasticities, i.e. elasticities that take into account cross-commodity substitution and advertising spill-over. Since for substitute goods the total advertising and price elasticities are 'both' smaller than their partial counterparts (Buse, 1958; Kinnucan, 1996), ignoring demand interrelationships may be innocuous in terms of defining the optimal intensity.

Table 2
The effect of food industry market power on the optimal generic advertising intensity for beef, US, 1998

Scenario/substitution elasticities (σ)	Ratio of optimal:actual intensity when marketing channel are[a]			
	Perfectly competitive	Oligopoly only ($\xi = 0.05$)	Oligopsonyonly ($\theta = 0.05$)	Oligopoly and oligopsony
No. 1: $\beta = 0.0005$ and $\eta = 0.78$				
0	1.23	1.16	0.93	0.87
0.25	0.86	0.83	0.75	0.73
0.50	0.69	0.68	0.65	0.64
0.72	0.60	0.60	0.60	0.59
No. 2: $\beta = 0.0005$ and $\eta = 0.56$				
0	1.72	1.57	1.29	1.17
0.25	1.10	1.06	0.99	0.96
0.50	0.85	0.85	0.84	0.83
0.72	0.73	0.74	0.75	0.76
No. 3: $\beta = 0.0005$ and $\eta = 0.42$				
0	2.29	2.02	1.72	1.51
0.25	1.34	1.30	1.25	1.21
0.50	1.00	1.01	1.02	1.04
0.72	0.85	0.87	0.91	0.94
No. 4: $\beta = 0.0011$ and $\eta = 0.56$				
0	3.78	3.45	2.84	2.58
0.25	2.41	2.34	2.18	2.11
0.50	1.87	1.86	1.84	1.83
0.72	1.61	1.62	1.66	1.68

[a] Computed using text Eq. (11) with $\varepsilon_b = 2$.

market power has a pronounced effect on producers' incentive to promote under fixed proportions, but considerably less impact under variable proportions for values of σ beyond about 0.25 (Table 2). For example, in scenario 1, where $\beta = 0.0005$ and $\eta = 0.78$, if $\sigma = 0$ the optimal/actual intensity ratios range from 1.23 under perfect competition to 0.87 under combined oligopoly–oligopsony power, a 29% reduction. If $\sigma = 0.25$, the corresponding range is from 0.86 to 0.73, a 15% reduction. For values of σ above about 0.50 market power's effect on promotion incentives is effectively neutralised.

Comparing oligopoly and oligopsony power, for equal conjectures ($\theta = \xi$) the latter has a larger impact on promotion incentives, as might be expected since $\varepsilon_a < \eta$. For example, under scenario 2, where $\beta = 0.0005$ and $\eta = 0.56$, if $\sigma = 0.25$ the intensity ratio declines from 1.10 to 1.06 under oligopoly to 0.99 under oligopsony, the latter being sufficient to indicate overspending. If consumers are relatively responsive to promotion such that $\beta = 0.0011$ and $\eta = 0.56$ (scenario 4) and $\sigma = 0.25$, oligopsony power reduces the intensity ratio from 2.41 to 2.18, compared to 2.34 for oligopoly power. In this case, the combined effect of oligopoly and oligopsony power is to depress the intensity ratio to 2.11, which is only slightly below the ratio for oligopsony alone. Bearing in mind that empirical evidence suggests that $\theta > \xi$ for beef, these results suggest that oligopsony power exerts the stronger influence on promotion incentives in the beef marketing channel.

Overall it appears that in the case of beef, market power is not an important determinant of promotion incentives, at least for the levels of market power contemplated in this study. Much more important are the advertising elasticity, the retail demand elasticity, and the factor substitution elasticity itself. For example, if $\sigma > 0.50$, the 1998 spending level of 28.3 mUS$ would be considered excessive for values of η greater than about 0.5 when $\beta = 0.0005$, our 'best-bet' advertising elasticity. Conversely, if $\beta = 0.0011$, Kinnucan et al.'s (1997) most optimistic estimate of this parameter, intensity ratios are uniformly <1 when $\eta = 0.56$ (the parameter's middle estimate), which would suggest that the observed expenditure level is too low. For example, in this instance and setting $\sigma = 0.72$ (Wohlgenant's (1989) estimate) the intensity ratios range from 1.61 for perfect competition to 1.68 for oligopoly–oligopsony power, which suggests an approximate 60% budget increase would be needed to reach the economic optimum.

5.3. Sensitivity analysis

To shed further light on interplay between factor substitution and promotion incentives in the presence of market power, we conducted sensitivity analysis by setting $\beta = 0.0005$ and $\eta = 0.56$, our 'best-bet' values for these parameters, and varying σ, ε_b, ξ, and θ as indicated in Table 3. Specifically, we set σ alternatively to 0.1 and 0.3, values that would appear to be appropriate for a short-run time horizon, say 1 year or less. Similarly, ε_b is set alternatively to one and infinity, values that encompass the baseline value of 2.00 and reflect the exogeneity assumption that underlies Wohlgenant's (1993) and Zhang and Sexton's (2000) analyses. The conjectural elasticities are varied between 0.01 and their posited upper limits of 0.10 in selected steps to identify more clearly market power effects over the short-run time horizon contemplated here.

The results suggest that treating P_b as exogenous is innocuous (Table 3). In particular, although optimal/actual intensity ratios increase with ε_b, these increases are too small to be of consequence. This result, which is consistent with results obtained by Kinnucan (1997) in a multi-market context, suggests that the simpler expressions Eqs. (12) and (14) are adequate for determining optimal intensity.

Turning to the effect of market power on promotion incentives, the main point of this exercise, it can be seen that σ is a pivotal parameter. In particular, if $\sigma = 0.3$ the intensity ratios are predominately below unity, meaning that the program is probably over-funded. Conversely, if $\sigma = 0.1$ the intensity ratios are mostly greater than unity, implying the opposite. Comparing Tables 2 and 3, perhaps most striking is the fact that even modest departures from fixed proportions can

Table 3
Sensitivity of the optimal generic advertising intensity to conjectural elasticities ξ and θ and marketing services' supply elasticity ε_b, US beef industry, 1998

Parameter value (θ)	Optimal/actual intensity when $\sigma = 0.1$[a]		Optimal/actual intensity when $\sigma = 0.3$[a]	
	$\varepsilon_b = 1.0$	$\varepsilon_b = \infty$	$\varepsilon_b = 1.0$	$\varepsilon_b = \infty$
$\xi = 0.01$				
0.01	1.28	1.35	0.98	1.05
0.03	1.19	1.24	0.96	1.01
0.07	1.04	1.07	0.91	0.94
0.10	0.95	0.97	0.87	0.89
$\xi = 0.03$				
0.01	1.25	1.32	0.97	1.04
0.03	1.16	1.21	0.95	1.00
0.07	1.02	1.04	0.90	0.93
0.10	0.93	0.94	0.86	0.88
$\xi = 0.07$				
0.01	1.19	1.25	0.96	1.01
0.03	1.10	1.14	0.93	0.97
0.07	0.96	0.98	0.88	0.90
0.10	0.88	0.89	0.84	0.85
$\xi = 0.10$				
0.01	1.14	1.19	0.94	0.99
0.03	1.06	1.09	0.91	0.95
0.07	0.92	0.93	0.86	0.88
0.10	0.84	0.84	0.82	0.83

[a] Based on text Eq. (11) with $\eta = 0.56$ and $\beta = 0.0005$.

have a pronounced influence on promotion incentives, both in terms of lowering the optimal intensity, and in terms of attenuating the market power effect. This suggests that accurate estimation of σ could have significant payoffs in terms of improved promotion decisions.

Given the attenuation in the market power effect associated with factor substitution, the question arises as to whether the D–S rule, modified to account for factor substitution, might be adequate for defining optimal intensity. To determine this, and to determine the importance of including the 'feedback effect' in the analysis, we simulated Eqs. (12)–(14) for alternative values of σ ranging from 0 to 0.7 with remaining parameters set to the values indicated in the footnote to Table 4. Focusing first on the case where $\sigma = 0$, Eqs. (12) and (13) both give an optimal intensity of 0.0733%. Thus, the feedback effect is negligible, as claimed. Turning to Eq. (14), the modified D–S rule gives an optimal intensity of 0.0893% when $\sigma = 0$. Since Eq. (14) ignores market power, the modified D–S rule overstates the optimal advertising intensity by 22% for the considered parameter values. However, this overstatement decreases steadily as σ increases in, and becomes negligible for $\sigma \geq 0.4$. Thus, in the case of US beef it appears that the D–S rule, suitably modified to account for factor substitution, suffices to indicate optimal advertising intensity. Conversely, a rule that includes market power but excludes factor substitution would cause optimal intensity to be overstated by a non-trivial amount for $\sigma \geq 0.4$ (compare last two columns in Table 4).

Table 4
Optimal advertising intensities computed from different formulae under fixed and variable proportions, US beef industry, 1998

Substitution elasticity (σ)	Optimal intensities (%)[a]			Ratio	
	$\bar{\phi}'_R$	$\bar{\phi}^{ZS}_R$	$\bar{\phi}^{DS}_R$	$\bar{\phi}^{ZS}_R/\bar{\phi}'_R$	$\bar{\phi}^{DS}_R/\bar{\phi}'_R$
0 (Fixed proportions)	0.0733	0.0733	0.0893	1.00	1.22
0.1	0.0648	0.0733	0.0744	1.13	1.15
0.2	0.0580	0.0733	0.0638	1.26	1.10
0.3	0.0525	0.0733	0.0558	1.40	1.06
0.4	0.0480	0.0733	0.0496	1.53	1.03
0.5	0.0442	0.0733	0.0447	1.66	1.01
0.6	0.0409	0.0733	0.0406	1.79	0.99
0.7	0.0381	0.0733	0.0372	1.93	0.98

[a] Computed using text Eqs. (12)–(14) with $\beta = 0.0005$, $\eta = 0.56$, $\theta = 0.10$, $\Omega = 0$, and $S_a = 0.472$. *Note*: actual intensity is 0.056%.

6. Concluding comments

The basic theme of this paper is that substitution possibilities in the marketing channel play an important role in determining farmers' incentives to promote. Building on this theme, we develop a model of oligopoly–oligopsony power in a multi-stage production system that includes fixed proportions (Leontief) technology as a special case. Results suggests that food industry market power does indeed influence promotion incentives at the farm level, as previous research suggests. However, our analysis suggests that the factor substitution elasticity σ plays a pivotal role. In particular, the inverse relationship between market power and promotion incentives found (for example) in Zhang and Sexton's (2000) study is attenuated when $\sigma > 0$. In fact, the attenuation is such that for plausible parameter values the Dorfman–Steiner rule, suitably modified to account for factor substitution, suffices to determine optimal advertising intensity in the US beef sector.

Although accounting for market power does not appear to be important in determining promotion incentives in the US beef sector, this does not mean that market power *per se* is unimportant. In particular, study results suggest that owing to the inelastic demand for beef, even a modest degree of oligopoly power (as measured by the Lerner index) can have significant negative effects on demand at the farm level. In fact, if generic advertising makes retail demand less price elastic, as might be expected if it emphasises product differentiation, this advertising might be counterproductive in that the oligopoly distortion would be exacerbated. Empirical evidence to date suggests beef advertising has not affected the demand elasticity (Brester and Schroeder, 1995, pp. 975–976). Still, this is a point that program managers might want to bear in mind when developing future campaigns.

A caveat in interpreting our results is that they are based on the assumption that the retail demand elasticity is unaffected by changes in market power. Although we do not believe this assumption to be limiting, it needs to be tested before one can have complete confidence in the accuracy of the results. In the meantime, study results showing a strong inverse relationship between optimal intensity and σ suggest that taking factor substitution into account could lead to improved generic advertising decisions. The model presented in this paper provides a framework for analysing such decisions in instances where middlemen possess market power, advertising funds are raised through a per-unit assessment on farm output, and the price of marketing services is endogenous.

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Appendix A. Theoretical restrictions on Lerner indices

Since constant returns to scale implies that factor payments exhaust industry revenue in perfectly competitive equilibrium, it should not be surprising that CRTS places restrictions on Ψ and Ω in imperfectly competitive equilibrium. To derive these restrictions, note first that by Euler's theorem text Eq. (2) can be rewritten as:

$$x = f_a a + f_b b\cdot \tag{A.1}$$

Substituting text Eqs. (3) and (4) into this expression yields:

$$(1-\Psi)P_x x = P_a a(1+\Omega) + P_b b,$$

which may be expressed alternatively as:

$$P_x x = P_a a + P_b b + \pi \tag{A.2}$$

where $\pi = \Psi P_x x + \Omega P_a a$ is the excess profit (or 'rent') due to market power. Since this profit cannot exceed retail value, it follows immediately that Ψ has an upper limit of 1. In fact, since payments to a constitute a significant share of retail value and marketing costs are unavoidable, Ψ and Ω are both expected to be considerably <1 in most situations.

To see this more clearly we first divide Eq. (A.2) by $P_x x$ to yield:

$$1 = S_a + S_b + \Psi + \Omega S_a\cdot \tag{A.3}$$

From Eq. (A.3), if (for example) the farm share is 0.50 and marketing services' share is 0.30, then $\Psi + 0.5\Omega = 0.2$. In this case, Ψ has an upper limit of 0.2 and Ω of 0.4. As supply and demand for agricultural products are generally price inelastic, these limits may explain why point estimates of ξ and θ tend to be tiny when measured at the national level. (In *local* markets, supply and demand elasticities (and, therefore, ξ and θ) can be large due to small-trader effects. For an insightful discussion of this issue in an oligopsony context, see Sexton (1990).)

To impose restriction Eq. (A.3) it is convenient to rewrite the expression as follows:

$$1 = \frac{S_a(1+\Omega)/(1-\Psi) + S_b}{(1-\Psi)}, \tag{A.4}$$

or, more compactly,

$$1 = \kappa_a' + \kappa_b, \tag{A.5}$$

where $\kappa_a' = S_a(1+\Omega)/(1-\Psi)$ and $\kappa_b = S_b/(1-\Psi)$ are 'value-share' terms (to use Waterson's (1980) terminology). In this study, restriction Eq. (A.5) is imposed by setting $\kappa_b = 1-\kappa_a'$, as noted in Appendix B.

Finally, Holloway (1991, p. 983) defines the value–share terms as follows:

$$\omega_i = \frac{S_i(\theta+\eta)}{\eta} \quad i = a, b,$$

which, in our notation, are equivalent to:

$$\omega_i = S_i(1-\Psi) \quad i = a, b. \tag{A.6}$$

That Eq. (A.6) is problematic can be seen by imposing the restriction that $\omega_a + \omega_b = 1$ to yield:

$$S_a + S_b = \frac{1}{(1-\Psi)} \geq 1,$$

which implies that oligopoly power *increases* factor payments. This neither accord with economic logic, nor is it consistent with Eq. (A.3), which implies that $S_a + S_b \leq 1$. Thus, we conclude that Holloway's (1991) definition is incorrect.

Appendix B. Derivation of Eqs. (3′) and (4′)

Here we derive Eqs. (3′) and (4′), and in the process show that the equations' 'coefficients' are properly interpreted as parameters. The first step is to note that by CRTS the following identity holds (see, e.g. Silberberg, 1978, p. 316):

$$f_{ab} = f_{ba} = \frac{f_a f_b}{x\sigma}, \tag{B.1}$$

where f_{ij} are second-order partial derivatives of Eq. (2).

Eq. (3′) may be derived by first expressing Eq. (3) in terms of percentage changes as follows:

$$P_a^* + (1+\Omega)^* = P_x^* + f_a^* + (1-\Psi)^*. \tag{B.2}$$

Since Ω and Ψ are parameters, it follows immediately that:

$$(1+\Omega)^* = \frac{\mathrm{d}(1+\Omega)}{(1+\Omega)} = \frac{\mathrm{d}\Omega}{(1+\Omega)} = \left[\frac{\Omega}{(1+\Omega)}\right]\left(\frac{\mathrm{d}\Omega}{\Omega}\right) = \varepsilon_\Omega \Omega^*, \tag{B.3a}$$

$$(1-\Psi)^* = \frac{\mathrm{d}(1-\Psi)}{(1-\Psi)} = \frac{-\mathrm{d}\Psi}{(1+\Psi)} = -\left[\frac{\Psi}{(1-\Psi)}\right]\left(\frac{\mathrm{d}\Psi}{\Psi}\right) = -\eta_\Psi \Psi^*, \tag{B.3b}$$

where ε_Ω and η_Ψ are fixed constants.

Turning to the f_a^* term in Eq. (B.2) and noting that $f_a = f_a(a, b)$ we have:

$$f_a^* = \frac{\mathrm{d}f_a}{f_a} = \frac{(f_{aa}\mathrm{d}a + f_{ab}\mathrm{d}b)}{fa},$$

or, equivalently:

$$f_a^* = \left(\frac{af_{aa}}{f_a}\right)a^* + \left(\frac{bf_{ab}}{f_a}\right)b^*, \tag{B.4}$$

where $(af_{aa}/f_a) < 0$ and $(bf_{ab}/f_a) > 0$ are 'elasticities' that indicate how small percentage changes in a and b translate into percentage changes in a's marginal product. Since Eq. (B.4) is homogenous of degree zero (by Euler's theorem), these elasticities must sum to zero. Hence, imposing $af_{aa}/f_a = -bf_{ab}/f_a$ we have:

$$f_a^* = -\left(\frac{bf_{ab}}{f_a}\right)a^* + \left(\frac{bf_{ab}}{f_a}\right)b^*. \tag{B.4a}$$

The second-order cross partials are eliminated from Eq. (B.4a) by substituting Eq. (B.1) to yield:

$$f_a^* = -\left(\frac{bf_b}{x\sigma}\right)a^* + \left(\frac{bf_b}{x\sigma}\right)b^*. \tag{B.4b}$$

To eliminate f_b from Eq. (B.4b) we substitute text Eq. (4) to yield:

$$f_a^* = -\left[\frac{S_b}{(1-\Psi)\sigma}\right]a^* + \left(\frac{S_b}{(1-\Psi)\sigma}\right)b^*. \tag{B.5}$$

In this study, S_b is treated as endogenous, dependent on the initial equilibrium value for farm share and the posited values of the Lerner indices. In particular, as shown in Appendix A (Eq. (A.3)), the cost–share variables and market-power parameters are related as follows:

$$S_b = 1 - \Psi - S_a(1+\Omega) \tag{B.6}$$

where S_a is set to its value in *initial* equilibrium.

Substituting Eq. (B.6) into Eq. (B.5) and combining terms yields:

$$f_a^* = -\left[\frac{(1-\kappa_a')}{\sigma}\right]a^* + \left[\frac{(1-\kappa_a')}{\sigma}\right]b^*, \tag{B.7}$$

where $\kappa_a' = S_a^{\mathrm{o}}(1+\Omega)/(1-\Psi)$. Substituting Eqs. (B.7) and (B.3) into Eq. (B.2) and rearranging gives:

$$P_a^* = -\left[\frac{(1-\kappa_a')}{\sigma}\right]a^* + \left[\frac{(1-\kappa_a')}{\sigma}\right]b^* + P_x^* - \eta_\Psi\Psi^* - \varepsilon_\Omega\Omega^*, \tag{B.8}$$

which is identical to Eq. (3′). Since the S_a term in κ_a' is fixed at its initial equilibrium value, the bracketed terms in Eq. (B.8) are properly regarded as fixed coefficients, as are η_Ψ and ε_Ω.

Turning to Eq. (4′), this equation may be derived in a similar fashion by first expressing Eq. (4) in percentage changes as follows:

$$P_b^* = P_x^* + f_b^* + (1-\Psi)^*. \tag{B.9}$$

Noting that $f_b = f_a(a, b)$ the f_b^* term in Eq. (B.9) is equivalent to:

$$f_b^* = \left(\frac{af_{ba}}{f_b}\right)a^* + \left(\frac{bf_{bb}}{f_b}\right)b^*.$$

Imposing homogeneity and substituting Eq. (B.1) yields:

$$f_b^* = -\left(\frac{af_a}{x\sigma}\right)a^* - \left(\frac{af_a}{x\sigma}\right)b^*.$$

Substituting Eq. (3) to eliminate f_a yields:

$$f_b^* = \left[\frac{S_a^{\text{o}}(1+\Omega)}{(1-\Psi)\sigma}\right]a^* - \left[\frac{S_a^{\text{o}}(1+\Omega)}{(1-\Psi)\sigma}\right]b^*,$$

which may be written more compactly as:

$$f_b^* = \left(\frac{\kappa_a'}{\sigma}\right)a^* - \left(\frac{\kappa_a'}{\sigma}\right)b^*. \qquad \text{(B.10)}$$

Substituting Eqs. (B.10) and (B.3b) into Eq. (B.9) yields:

$$P_b^* = \left(\frac{\kappa_a'}{\sigma}\right)a^* - \left(\frac{\kappa_a'}{\sigma}\right)b^* + P_x^* - \eta_\Psi \Psi^*, \qquad \text{(B.11)}$$

which is identical to Eq. (4′). For the reasons cited earlier, the coefficients of the asterisked terms in Eq. (B.11) are properly regarded as fixed constants.

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