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Optimal Commodity Advertising in Bilateral Oligopoly

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Abstract

This study derives an optimal commodity advertising intensity rule for a vertically related market under bilateral oligopoly. The new optimality condition derived in this study extends the seminal Dorfman-Steiner Theorem [1] and recently published optimal advertising conditions by two major aspects. First, we strengthen the previous work by considering potential market power exertion in all buying (input) and selling (output) markets, *i.e.*, all four adjacent upstream and downstream markets of processors and retailers. Second, we use a primal production function approach to avoid the symmetry assumption that many earlier studies imposed on conjectural elasticities of input and/or output markets. Our new condition suggests that, without considering the potential market power exertions, the optimal advertising intensity and expenditures are overestimated. Our derivation also indicates that previous optimal advertising conditions derived under the assumption of fixed proportion technology could underestimate the optimal intensity and expenditures, particularly when advertising elasticity is elastic.

Keywords

Bilateral Market Power, Optimal Advertising, Production Function

1. Introduction

Generic commodity advertising has pursued to increase producers' profits for various agricultural commodities. The money to fund these commodity advertising programs is collectively raised through producers' checkoff programs, which require producers to pay a specified amount of money on per unit or value assessment. One important issue in running these advertising programs is to determine the condition of optimal advertising intensity. Beginning with Dorfman and Steiner [1]'s seminal work, numerous studies have examined the opti-

mality of advertising expenditures in both economics and agricultural economics literature [1]-[6]. Among these studies, only a few studies, e.g., [4] [5] [6], consider imperfect competition in food processing and retailing sectors. However, several studies have found the existence of imperfect competition in these sectors as they have become increasingly concentrated in recent years [7] [8] [9] [10].

Therefore, it should be important to consider firms' imperfect competition behavior in determining their optimal advertising expenditures because firm's profit maximizing price and quantities might differ under the changing market structure.

The objective of this study is to derive an optimal commodity advertising intensity rule for a vertically related market under bilateral oligopoly. The new optimality condition extends the seminal Dorfman-Steiner Theorem and recently published optimal advertising conditions by two major aspects. First, we strengthen the previous work by considering potential market power exertion in all buying (input) and selling (output) markets, *i.e.*, all four adjacent upstream and downstream markets of processors and retailers. Second, we use a primal production function approach to avoid the symmetry assumption that many earlier studies imposed on conjectural elasticities of input and/or output markets. Specifically, the new framework allows potentially different conjectural elasticities in all four adjacent upstream and downstream markets without imposing the assumption of fixed proportion technology. Therefore, unlike previous studies, our derivation is flexible enough to allow the four-way bilateral market power exertion from retailers and processors that can be different in each of the four markets. Our new condition suggests that, without considering the potential market power exertions, the optimal advertising intensity and expenditures are overestimated, while imposing the fixed proportion technology could underestimate the optimal intensity and expenditures, particularly when advertising elasticity is elastic.

The next section reviews related literature focusing on the derivation of the optimal advertising framework. Section 3 provides a step by step derivation of new optimal advertising intensity rule considering bilateral oligopoly of upstream and downstream markets. Section 4 summarizes our results and discuss some insights and policy implications that can be drawn from our main findings. **Appendix 1** and **Appendix 2** present an extended derivation of the optimal advertising intensity and comparative static results.

2. Literature Review

The Dorfman and Steiner Theorem [1] characterizes the optimal advertising condition as the equality of the ratio of advertising expenditures (A) to sales (PQ, here P and Q represent sales price and quantity, respectively) with the ratio of the advertising elasticity (η_A) to the absolute value of price elasticity of demand $\left(\left|\eta_p\right|\right)$, *i.e.*, $\frac{\eta_A}{\left|\eta_p\right|} = \frac{A}{PQ}$. The Dorfman and Steiner theorem is derived

for the case where either sales price or quantity is controlled. Goddard and McCutcheon [3] derivation of the optimal advertising rule show that optimal advertising conditions are the same whether quantity is assumed fixed or whether both quantity and price are allowed to adjust to advertising. Unlike previous two studies, Nerlove and Waugh [2] are based on the assumption that producers have alternatives for the use of collected funds spent on advertising. Therefore, the study recognizes alternative uses of the funds such as buying government bonds and equate the marginal returns of advertising to the rate of returns on alternative forms of investment (ρ), while also considering the supply response to advertising. Then, the corresponding optimal advertising condition becomes:

$$\frac{\eta_A}{\left(\varepsilon+\left|\eta_p\right|\right)(1+\rho)}=\frac{A}{PQ},$$

where ε is the supply elasticity. Including these three studies reviewed above, the early derivations of the optimal advertising condition in the commodity advertising literature mostly derived the optimality condition under the competitive market structure.

A few recent studies reflect the change in market structure of food processing and retailing sectors in deriving the optimality condition of advertising. Zhang and Sexton [4] derive optimal conditions of commodity advertising for agricultural markets where processing and distribution sectors exhibit oligopoly and oligopsony power. Kinnucan [5] investigates the impact of food processors' market power on farmers' optimal advertising expenditures, while assuming the existence of market power in the food industry. Although some studies including Zhang and Sexton [4] and Kinnucan [5] derive the optimal advertising intensities under imperfectly competitive markets, these studies tend to focus on imperfect competition in processing sector alone or at best in an integrated processing-retailing sector without fully considering the bilateral oligopoly between processors and retailers. However, recent studies on the retailer-processor relationship find that retailers exercise a larger influence in food distribution than do processors [10] [11] [12]. The existence of slotting and promotional fees to processors in many retailer chains is also an evidence of retailers' exercise of market power over processors [13]. Most recently, Chung, Eom, and Yang [10] develop the advertising intensity formula that considers bilateral imperfect competition between processors and retailers. Although the recent study extends previous studies, it is still limited in deriving conjectural elasticities (representing processors' and retailers' market power exertion) due to the use of fixed proportions technology assumption that is imposed on the cost function approach. Under the fixed proportions technology, retailers' and processors' conjectural elasticities are all identical in output and input markets, which is inconsistent with oligopoly and oligopsony theory and is solely a result of the imposed production technology in the dual approach.

3. Derivation of Optimal Commodity Advertising Intensity in Bilateral Oligopoly

For most commodity advertising programs, the marketing board (not by individual firms) of an industry decides on the level of advertising expenditures given checkoff fund that the industry collects. However, the collected checkoff funds are also affected by the level of advertising expenditures because the advertising expenditures induces changes in industry sales, while the fund is collected on per unit or value of sales. Therefore, it is noted that the advertising expenditures are endogenous to equilibrium prices and quantities in the market under consideration [4] [6] [14]. In our study, we consider a vertically related industry where retailers and processors exert market power in all buying and selling markets, while producers are competitive in selling their products. We assume that bilateral oligopoly and oligopsony equilibria between retailers and processors are determined simultaneously in this study [6] [15] [16])[1]. To represent the marketing board's decision making process on the level of advertising expenditures and the industry's bilateral oligopoly and oligopsony equilibria, we first solve retailers' and processors' profit maximization conditions to obtain a set of market equilibrium conditions and to derive marginal effects of a change in checkoff assessment rate on equilibrium prices and quantities. Then, the optimal advertising intensity is determined from the derived marginal effects, while considering the condition of the marketing board's producer surplus maximization.

Let's define retail demand and farm supply functions, and identity condition as:

$$Y^r = D^r\left[P^r, A(t)\right], \tag{1}$$

$$Y^f = S^f\left[P^f(t), t\right], \tag{2}$$

$$Y^r = g\left[Y^p\left(Y^f\right)\right], \tag{3}$$

where Y^r, Y^p and Y^f are aggregate product quantities at retail, processing and farm level, respectively, and P^r and P^f are market prices received by retailer and producers; t is the per-unit tax on farm production; and the advertising expenditure, A, is defined as $A = t * Y^f$, assuming all collected money is utilized for advertising.

[1]The bilateral imperfect competition between processor and retailer (in particular, processor's oligopoly and retailer's oiligopsony power) can be determined through the dominance of either processor or retailer, collusion, or bargaining [24]. If either processor or retailer dominates, price and quantity are set by buyer or seller. If the two collude, equilibrium price and quantity are determined to jointly maximize profits. If they bargain, no dominance between buyer and seller is resulted. In many cases, the bargaining relationship seems to be more realistic particularly in U.S. food processing and retail-grocery industries. Therefore, several previous studies in the industrial organization literature develop bilateral oligopoly/oligopsony models that potentially allow market power for both buyers and sellers [15] [25] [26]. For example, Azzam's [25] econometric analysis shows that neither sellers nor buyers dominate between the U.S. beef packing industry and retail-grocery industry. The industry data also suggest that both retailers and packers may exercise oligopsony and oligopoly power, respectively: the CR4 in the U.S. beef packing industry in 2011 was 84% [27], while about 60% of four largest grocery chains' beef procurement in U.S. is directly from packers [25].

Production functions for a retailer and a processor can also be defined as: $y^r = f_r\left(y^p, x_k\right)$ and $y^p = f_p\left(y^f, z_u\right)$, respectively, where input factors, y^p and y^f represent raw material inputs for retail and processed products, and x_k and z_u represent other inputs like labor, capital, and materials that are purchased from a competitive market. Then, the profit maximization problem for the ith retailer can be written as:

$$\max \Pi_i^r = P^r\left(Y^r\right)y_i^r - P^p\left(Y^p\right)y_i^p - \sum_{k=1}^{3} v_k x_k, \tag{4}$$

where $Y^r = \sum_{i=1}^{M} y_i^r, Y^p = \sum_{i=1}^{N} y_i^p$, and P^p and v_k denote prices of raw material (Y^p) and other inputs (x_k). The first-order condition of the retailer's problem leads to:

$$P^r f_{y^p}\left(1 + \frac{\xi_i}{H\left(Y^r, t\right)}\right) = P^p\left(1 + \frac{\theta_i}{\varepsilon^p}\right), \tag{5}$$

where $\xi_i = \frac{\partial Y^r}{\partial y_i^r}\frac{y_i^r}{Y^r}$ and $\theta_i = \frac{\partial Y^p}{\partial y_i^p}\frac{y_i^p}{Y^p}$ are retailer *i's* conjectural elasticities reflecting the degree of competition in selling retail output and procuring processed input, respectively;

$$H\left(Y^r, t\right) = \frac{\mathrm{d}Y^r}{\mathrm{d}P^r}\frac{P^r}{Y^r} = \frac{\eta^r}{\left(1 - \eta_A\right)} f_{y^p}$$

is the total elasticity of retail demand; η^r and η_A are the partial price elasticity of demand and the advertising elasticity at the retail level, respectively; $\varepsilon^p = \frac{\partial Y_s^p}{\partial P^p}\frac{P^p}{Y_s^p}$ is the elasticity of processed input supply; and $f_{y_i^p} = \frac{\partial y^r}{\partial y^p}$ and $f_{y^f} = \frac{\partial y^p}{\partial y^f}$ are the marginal product of the processed input used by the retailer and the marginal product of the farm input used by the processor, assuming symmetric productivity across firms.

Similarly, the profit maximization problem for the jth processor can be expressed as:

$$\max \Pi_j^p = P^p\left(Y^p\right)y_j^p - W^f\left(Y^f\right)y_j^f - \sum_{l=1}^{3} w_l z_l, \tag{6}$$

where $Y^f = \sum_{j=1}^{O} y_j^f$; w_l denotes the price of other input, z_l; W^f is the price paid by processors including the per-unit check-off amount assessed to producers, which forms the relationship, $W^f = P^f + t$. Then, the first-order condition of this profit maximization problem can be written in elasticity form as:

$$P^p f_{y^f}\left(1 + \frac{\phi_j}{\eta^p}\right) = p^f\left(Y^f\right)\left(1 + \frac{\varpi_j}{\varepsilon^f}\right) + t, \tag{7}$$

where

$$\phi_j = \frac{\partial Y^p}{\partial y_j^p}\frac{y_j^p}{Y^p} \quad \text{and} \quad \varpi_j = \frac{\partial Y^f}{\partial y_j^f}\frac{y_j^f}{Y^f}$$

represent processor *j's* conjectural elasticities reflecting the degree of competition in selling processed output and procuring farm input, respectively;

$$\eta^p = \frac{\partial Y_d^p}{\partial P^p}\frac{P^p}{Y_d^p} \quad \text{and} \quad \varepsilon^f = \frac{\partial Y^f}{\partial P^f}\frac{P^f}{Y^f}$$

are the elasticity of derived demand at processor level and the supply elasticity at farm level, respectively. Solving equation (7) for P^p and substituting into equation (5) result in:

$$P^r\left(1+\frac{\xi_i}{H\left(Y^r,t\right)}\right) = \frac{1}{\left(1+\frac{\phi_j}{\eta^p}\right)f_{y^p}f_{y^f}}\left[p^f\left(Y^f\right)\left(1+\frac{\varpi_j}{\varepsilon^f}\right)+t\right]\left(1+\frac{\theta_i}{\varepsilon^p}\right). \quad (8)$$

To derive effects of a change in assessment rate, *t*, on equilibrium prices and quantities and first-order conditions from processors' and retailers' profit maximizations, we totally differentiate Equations (1)-(3), and Equation (8) as[2,3]:

$$\frac{\mathrm{d}Y^r}{\mathrm{d}t} = \frac{\mathrm{d}P^r}{\mathrm{d}t} + \frac{\partial D}{\partial A}\frac{\mathrm{d}A}{\mathrm{d}t} = \frac{\partial D}{\partial P^r}\frac{\mathrm{d}P^r}{\mathrm{d}t} + \frac{\partial D}{\partial A}\left[Y^f + t\frac{\mathrm{d}Y^f}{\mathrm{d}t}\right], \quad (9)$$

$$\frac{\mathrm{d}Y^f}{\mathrm{d}t} = \frac{\partial S^f}{\partial P^f}\frac{\mathrm{d}P^f}{\mathrm{d}t}, \quad (10)$$

$$\frac{\mathrm{d}Y^r}{\mathrm{d}t} = f_{y^p}f_{y^f}\frac{\partial S^f}{\partial P^f}\frac{\mathrm{d}P^f}{\mathrm{d}t}, \quad (11)$$

$$\begin{aligned}
&\left(1+\frac{\xi}{H}\right)\frac{\mathrm{d}P^r}{\mathrm{d}t} - \frac{\xi P^r}{H^2}\frac{\mathrm{d}H}{\mathrm{d}t} \\
&= -\frac{1}{\left(f_{y^p}\right)^2 f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)}\frac{\mathrm{d}f_{y^p}}{\mathrm{d}t}\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\left(1+\frac{\theta}{\varepsilon^p}\right) \\
&\quad -\frac{1}{\left(f_{y^f}\right)^2 f_{y^p}\left(1+\frac{\phi}{\eta^p}\right)}\frac{\mathrm{d}f_{y^f}}{\mathrm{d}t}\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\left(1+\frac{\theta}{\varepsilon^p}\right) \\
&\quad +\frac{1}{f_{y^f}f_{y^p}\left(1+\frac{\phi}{\eta^p}\right)^2}\frac{\phi}{\left(\eta^p\right)^2}\frac{\mathrm{d}\eta^p}{\mathrm{d}t}\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\left(1+\frac{\theta}{\varepsilon^p}\right) \\
&\quad +\frac{1}{f_{y^p}f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)}\left[\left(1+\frac{\varpi}{\varepsilon^f}\right)\frac{\mathrm{d}P^f}{\mathrm{d}t} - \frac{\varpi P^f}{\left(\varepsilon^f\right)^2}\frac{\mathrm{d}\varepsilon^f}{\mathrm{d}t}+1\right]\left(1+\frac{\theta}{\varepsilon^p}\right) \\
&\quad -\frac{1}{f_{y^p}f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)}\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\frac{\theta}{\left(\varepsilon^p\right)^2}\frac{\mathrm{d}\varepsilon^p}{\mathrm{d}t}
\end{aligned}. \quad (12)$$

Equation (12) can be rewritten in elasticity form as:

[2]Firm specific subscripts, *i* and *j*, have been omitted to simplify notation, while denoting the representative firm behavior for each sector.

[3]Maplesoft [28] was used for computations in this paper.

$$\left(1+\frac{\xi}{H}\right)\frac{\mathrm{d}P^r}{\mathrm{d}t}-\frac{\left(1+\frac{\theta}{\varepsilon^p}\right)}{f_{y^p}f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)}\left(1+\frac{\varpi}{\varepsilon^f}\right)\frac{\mathrm{d}P^f}{\mathrm{d}t}$$

$$=-\frac{\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\left(1+\frac{\theta}{\varepsilon^p}\right)}{tf_{y^p}f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)}F_{f_{y^p},t}-\frac{\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\left(1+\frac{\theta}{\varepsilon^p}\right)}{tf_{y^f}f_{y^p}\left(1+\frac{\phi}{\eta^p}\right)}F_{f_{y^f},t}$$

$$+\frac{\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\left(1+\frac{\theta}{\varepsilon^p}\right)}{f_{y^f}f_{y^p}\left(1+\frac{\phi}{\eta^p}\right)^2}\frac{\phi}{t\eta^p}E_{\eta^p,t}$$

$$+\frac{1}{f_{y^p}f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)}\left[-\frac{\varpi P^f}{t\varepsilon^f}E_{\varepsilon^f,t}+1\right]\left(1+\frac{\theta}{\varepsilon^p}\right) \quad , \tag{13}$$

$$-\frac{1}{f_{y^p}f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)}\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\frac{\theta}{t\varepsilon^p}E_{\varepsilon^p,t}+\frac{\xi P^r}{tH}E_{H,t}$$

where

$$E_{\eta^p,t}=\frac{\mathrm{d}\eta^p}{\mathrm{d}t}\frac{t}{\eta^p},\quad E_{\varepsilon^p,t}=\frac{\mathrm{d}\varepsilon^p}{\mathrm{d}t}\frac{t}{\varepsilon^p},\text{ and }\quad E_{\varepsilon^f,t}=\frac{\mathrm{d}\varepsilon^f}{\mathrm{d}t}\frac{t}{\varepsilon^f}$$

are the percentage change in elasticities of processors' derived demand and supply, and the elasticity of farm supply in response to one percent change in check-off assessment rate *t*, respectively. $E_{H,t}$ represents the percentage change in total demand elasticity *H* in response to one percent change in the assessment rate *t*.

$$F_{y^p,t}=\frac{\mathrm{d}f_{y^p}}{\mathrm{d}t}\frac{t}{f_{y^p}}\quad\text{and}\quad F_{y^f,t}=\frac{\mathrm{d}f_{y^f}}{\mathrm{d}t}\frac{t}{f_{y^f}}$$

are the percentage change in productivity of processed and farm inputs used at retail and processing sector, respectively, in response to one percent change of *t*. Rewriting Equations (9)-(11) and Equation (13) in a matrix form gives:

$$\begin{bmatrix} 1 & -\frac{\partial D}{\partial P^r} & -t\frac{\partial D}{\partial A} & 0 \\ 0 & 0 & 1 & -\frac{\partial S^f}{\partial P^f} \\ 1 & 0 & 1 & -f_{y^p}f_{y^f}\frac{\partial S^f}{\partial P^f} \\ 0 & \left(1+\frac{\xi}{H}\right) & 0 & -\frac{\left(1+\frac{\theta}{\varepsilon^p}\right)\left(1+\frac{\varpi}{\varepsilon^f}\right)}{f_{y^p}f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)} \end{bmatrix}\begin{bmatrix} \frac{\mathrm{d}Y^r}{\mathrm{d}t} \\ \frac{\mathrm{d}P^r}{\mathrm{d}t} \\ \frac{\mathrm{d}Y^f}{\mathrm{d}t} \\ \frac{\mathrm{d}P^f}{\mathrm{d}t} \end{bmatrix}=\begin{bmatrix} Y^f\frac{\partial D}{\partial A} \\ 0 \\ 0 \\ \Omega \end{bmatrix}, \tag{14}$$

where

$$\Omega = -\frac{\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\left(1+\frac{\theta}{\varepsilon^p}\right)}{tf_{y^p}f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)}F_{f_{y^p},t} - \frac{\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\left(1+\frac{\theta}{\varepsilon^p}\right)}{tf_{y^f}f_{y^p}\left(1+\frac{\phi}{\eta^p}\right)}F_{f_{y^f},t}$$
$$+\frac{\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\left(1+\frac{\theta}{\varepsilon^p}\right)}{f_{y^f}f_{y^p}\left(1+\frac{\phi}{\eta^p}\right)^2}\frac{\phi}{t\eta^p}E_{\eta^p,t}$$
$$+\frac{1}{f_{y^p}f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)}\left[-\frac{\varpi P^f}{t\varepsilon^f}E_{\varepsilon^f,t}+1\right]\left(1+\frac{\theta}{\varepsilon^p}\right)$$
$$-\frac{1}{f_{y^p}f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)}\left[P^f\left(1+\frac{\varpi}{\varepsilon^f}\right)+t\right]\frac{\theta}{t\varepsilon^p}E_{\varepsilon^p,t}+\frac{\xi P^r}{tH}E_{H,t}$$

Then, an industry's producer surplus maximization problem is considered to decide the optimal per-unit assessment rate, t^*, and consequently optimal advertising expenditure, A^*, for this industry [4] [6] [17]. From the first-order condition of this problem, we find that the optimal assessment rate is obtained at

$$\frac{\mathrm{d}Y^f}{\mathrm{d}t}=0,$$

i.e., when the supply-decreasing effect due to the higher assessment rate is just offset by the demand-increasing effect due to the adverting funded by the assessment [4]. Applying this optimality condition to $\frac{\mathrm{d}Y^f}{\mathrm{d}t}$, derived from matrix (14), results in:

$$\left(1+\frac{\xi}{H}\right)Y^f\frac{\mathrm{d}D}{\mathrm{d}A}=-\Omega\frac{\mathrm{d}D}{\mathrm{d}P^r}. \tag{15}$$

In the advertising literature, mixed views are observed on effects of advertising on demand elasticity. One group claims that advertising provides information about the existence of a brand or about its quality, increases consumer awareness of attributes of brands and reduced search costs, and thereby results in more elastic demand [18] [19] [20]. The other group argues that advertising creates product differentiations among brands that are otherwise difficult to distinguish. The product differentiation creates a barrier to entry into a market, increases brand loyalty, and reduces demand elasticity [21] [22]. For brevity, we assume that advertising has no impact on changing total elasticity of retail demand, elasticity of processor demand, and elasticities of processor and producer supply, *i.e.*,

$$E_{H,t}=E_{\eta^p,t}=E_{\varepsilon^p,t}=E_{\varepsilon^f,t}=0.$$

We also assume no impact of advertising on changing farm and processed input

productivities, *i.e.*, $F_{y^p,t} = F_{y^f,t} = 0$. Then, rewriting Equation (15) in an elasticity form and rearranging yields the optimal advertising intensity, I^*, as[4,5]:

$$I^* = \frac{A^*}{Y^{r*}P^{r*}} = -\frac{\eta_A}{\eta^r}\frac{1}{f_{y^f}f_{y^p}}\left(1+\frac{\xi}{H}\right)\left(\frac{1+\frac{\phi}{\eta^p}}{1+\frac{\theta}{\varepsilon^p}}\right). \tag{16}$$

Unlike the well-known Dorfman and Steiner theorem, where the optimal advertising intensity is equal to the ratio of the advertising elasticity relative to the price elasticity of demand, the newly derived optimal condition in equation (16) is determined not only by advertising and price elasticities at the retail level, but also by other market parameters such as productivities of farm and processed inputs at processing and retail level, retailers' and processors' bilateral market power parameters, and demand and supply elasticities of processors.

Impacts of changing parameters such as advertising elasticity, demand and supply elasticities, marginal productivities, and bilateral imperfect competition parameters on the optimal advertising intensity, I^*, are examined via comparative statics on Equation (16), and results are reported in **Appendix 2**. It is noted that $\left(1+\frac{\xi}{H}\right)>0$ and $\left(1+\frac{\phi}{\eta^p}\right)>0$ from Equation (5) and Equation (7), respectively, and η^r and η^p are negative by derivation. Then, $\frac{\partial I^*}{\partial \eta_A}, \frac{\partial I^*}{\partial |\eta^r|}, \frac{\partial I^*}{\partial f_{y^f}}$ and $\frac{\partial I^*}{\partial f_{y^p}}$ cannot be signed. However, if we assume an elastic η_A that is bigger than 1, *i.e.*, advertising campaigns are sufficiently effective to make numerators of each comparative static negative, then

$$\frac{\partial I^*}{\partial \eta_A} > 0, \frac{\partial I^*}{\partial |\eta^r|} < 0, \frac{\partial I^*}{\partial f_{y^f}} < 0 \text{ and } \frac{\partial I^*}{\partial f_{y^p}} < 0.$$

The comparative static results indicate that when advertising elasticity is elastic, the optimal advertising intensity, I^*, increases with advertising elasticity, η_A, while it decreases with absolute value of price elasticity of retail demand, $|\eta^r|$, and marginal productivities of processors' and retailers' raw material-inputs, f_{y^f} and f_{y^p}. Comparative static results, $\frac{\partial I^*}{\partial |\eta^p|} > 0, \frac{\partial I^*}{\partial \varepsilon^p} > 0$ and $\frac{\partial I^*}{\partial |H|} > 0$, show direct relationships between the optimal advertising intensity and absolute value of processors' price elasticity of demand, processors' supply elasticity, and absolute value of retailers' total demand. The direct and inverse relationships between the optimal advertising intensity and the related advertising, demand,

[4]The expanded derivation when $E_{H,t} \neq 0$, $E_{\eta^p,t} \neq 0$, $E_{\varepsilon^p,t} \neq 0$, $E_{\varepsilon^f,t} \neq 0$, $F_{y^p,t} \neq 0$, and $F_{y^f,t} \neq 0$, is provided in **Appendix 1**.

[5]The parameter representing processors' oligopsony power (ϖ) is excluded from (16) when restrictions on change in elasticities and productivities in response to advertising are imposed in the derivation.

and supply elasticites we found from Equation (16) are consistent with many studies in the literature [1] [4] [6]. The inverse relationship between productivity parameters and the intensity makes sense because as the productivities increase, we expect the retail output increases given processed and farm outputs. The impact of each market power parameter on the intensity can also be signed through comparative static analyses. Signs of the analyses, $\frac{\partial I^*}{\partial \xi}, \frac{\partial I^*}{\partial \phi}$ and $\frac{\partial I^*}{\partial \theta}$, are all negative, indicating that the increase in bilateral market power decreases the optimal advertising intensity. This result is consistent with empirical findings from Zhang and Sexton [4] and Chung, Eom, and Yang [6]. The newly developed optimal advertising rule in Equation (16) highlights two important findings. First, it shows the importance of considering market power exertions from retailers and processors. Without considering the potential market power exertions, the optimal advertising intensity is overestimated and therefore so is the optimal advertising expenditures. Secondly, it also shows that it could be problematic to estimate the optimal advertising intensity (the effectiveness of advertising programs) under the assumption of the fixed proportion technology. Many previous studies assume the fixed proportion and constant return to scale technology with Leontief coefficient 1 in converting from farm to retail products, which leads to identical input and output quantities at the retail, processing, and farm levels, and therefore, identical conjectural elasticities (market power exertion) in input and output markets at all levels. Equation (16) shows that such practices in previous studies could underestimate the optimal intensity and advertising expenditures, particularly when advertising elasticity is elastic (*i.e.*, greater than 1).

The advertising intensity derived by Zhang and Sexton [4] shows no direct effect of oligopsony power from the retailer-processing sector. When the processing sector is considered separately from the retailing sector (while including the import sector), Chung, Eom, and Yang [6] found that all four bilateral market power parameters affected the optimal condition. However, as stated earlier, the dual approach with the fixed proportion assumption used in Zhang and Sexton [4] and Chung, Eom, and Yang [6] resulted in the optimal advertising intensity framework with identical conjectural elasticities in output and input markets for retailers and processors. Equation (16), based on the primal approach without imposing the fixed proportion assumption, shows that three bilateral market power parameters, representing retailers' oligopoly and oligopsony as well as processors' oligopoly, are a part of determinants of the optimal advertising intensity. When the derivation allows advertising to change price elasticity of processor demand, supply elasticities of farm and processing sectors, and productivities of raw material inputs in retail and processing sectors, the extended condition includes all four bilateral market power parameters (see **Appendix 1**).

Equation (16) can also be reduced to optimal advertising rules derived from previous studies. For example, when no bilateral market power is considered,

while focusing only on the retail sector (*i.e.*, $\xi = \theta = \phi = \varpi = 0$; $f_{y^f} = f_{y^p} = 1$), the new optimal condition in Equation (16) equals to the Dorfman and Steiner condition. When an integrated retail and processing sector is assumed to exert its oligopoly and oligopsony market power, while imposing the fixed proportion technology (*i.e.*, $\theta = \phi = 0$; $f_{y^f} = f_{y^p} = 1$), Equation (16) can be reduced to the optimality condition derived by Zhang and Sexton [4]. Equation (16) can also be reduced to the optimal advertising rule of Chung, Eom, and Yang [6] when the fixed proportion technology (*i.e.*, $f_{y^f} = f_{y^p} = 1$) is considered with no import sector.

4. Summary and Conclusion

This study derives an optimal commodity advertising intensity rule for a vertically related market under bilateral oligopoly. The new optimality condition derived in this study extends the seminal Dorfman-Steiner Theorem and recently published advertising conditions by two major aspects. First, we strengthen the previous work by considering potential market power exertion in all buying (input) and selling (output) markets, *i.e.*, all four adjacent upstream and downstream markets of processors and retailers. Second, we use a primal production function approach to avoid the symmetry assumption that many earlier studies imposed on conjectural elasticities of input and/or output markets.

In our new derivation, the optimal advertising intensity shows the direct relationship with advertising elasticity, absolute value of processors' price elasticity of demand, processors' supply elasticity, and absolute value of total elasticity of retail demand, while it exhibits the inverse relationship with absolute value of price elasticity of retail demand, and processors' and retailers' raw material-input productivities when advertising elasticity is elastic. Our new optimal advertising rule also shows that the optimal level of advertising intensity (and expenditures) decreases with bilateral market power exertion. Therefore, findings from our derivation highlight two important points. First, without considering the potential market power exertions, the optimal advertising intensity and therefore, optimal advertising expenditures are overestimated. Second, previous optimal advertising conditions derived under the assumption of fixed proportion technology could underestimate the optimal advertising intensity and expenditures, particularly when advertising elasticity is elastic. Our findings should provide important policy implications particularly for marketing managers and members of marketing boards who work for commodity advertising programs. This new derivation will certainly help them find better estimates of optimal advertising expenditures and effectiveness of advertising programs.

One direction for future research could be to extend our modelling approach with cooperative play. Our model assumes bilateral market power exerted by retailers and processors on both sides of markets simultaneously and non-cooperatively. However, one can consider cases where retailers and processors look for cooperative strategies. In this case, the first stage of the play provides optimal

output and input levels that maximizes retailers and processors jointly. Then, the two sides negotiate a transfer price for the intermediate product to split the profit [23]. Another way to extend the current study might be to work with the extended intensity condition reported in **Appendix 1**. The extended formula is flexible enough to include parameters representing changes in price elasticity of processor demand, supply elasticities of farm and processing sectors, productivities of raw material inputs in retail and processing sectors due to advertising, and all four bilateral market power parameters. One potential drawback of using the extended condition is that comparative statics may not be able to provide clear directions for effects of market power and other related parameters on the optimal advertising intensity. To address this issue, a few studies show that one can develop a market equilibrium model and simulate the model using ranges of parameters and elasticities obtained from previous research [4] [6]. However, it might be difficult to get equilibrium solutions because of the complexity of the extended optimal advertising intensity condition.

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Appendix 1

The expanded derivation of optimal advertising intensity when $E_{H,t} \neq 0$, $E_{\eta^p,t} \neq 0$, $E_{\varepsilon^p,t} \neq 0$, $E_{\varepsilon^f,t} \neq 0$, $F_{y^p,t} \neq 0$, and $F_{y^f,t} \neq 0$.

$$I^* = \frac{A^*}{Y^{r*}P^{r*}} = \left[-\frac{1}{f_{y^f} f_{y^p}} \left\{ \left(\frac{\eta_A}{\eta^r} \frac{1}{f_{y^f} f_{y^p}} \right) \left(1 + \frac{\xi}{H} \right) + \frac{\xi}{H} E_{H,t} \right\} + f^f X \right] \frac{1}{\Psi}$$

where

$$X = \frac{\left(1+\frac{\varpi}{\varepsilon^f}\right)\left(1+\frac{\theta}{\varepsilon^p}\right)}{f_{y^p} f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)} \left(F_{f_{y^p},t} + F_{f_{y^f},t} \right)$$
$$- \frac{1}{f_{y^p} f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)} \left[\frac{\left(1+\frac{\varpi}{\varepsilon^f}\right)\left(1+\frac{\theta}{\varepsilon^p}\right)\phi E_{\eta^p,t}}{\left(1+\frac{\phi}{\eta^p}\right)\eta^p} \right.$$
$$\left. - \frac{\varpi E_{\varepsilon^f,t}\left(1+\frac{\theta}{\varepsilon^p}\right)}{\varepsilon^f} - \frac{\left(1+\frac{\varpi}{\varepsilon^f}\right)\theta E_{\varepsilon^p,t}}{\varepsilon^p} \right];$$

$$\Psi = -\frac{\left(1+\frac{\theta}{\varepsilon^p}\right)}{f_{y^p} f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)} \left(F_{f_{y^p},t} + F_{f_{y^f},t} \right)$$
$$+ \frac{1}{f_{y^p} f_{y^f}\left(1+\frac{\phi}{\eta^p}\right)} \left[\frac{\left(1+\frac{\theta}{\varepsilon^p}\right)}{\left(1+\frac{\phi}{\eta^p}\right)} \frac{\phi}{\eta^p} E_{\eta^p,t} + \left(1+\frac{\theta}{\varepsilon^p}\right) - \frac{\theta}{\varepsilon^p} E_{\varepsilon^p,t} \right].$$

Appendix 2

Comparative statics of the optimal advertising intensity with respect to each of parameters in Equation (16).

$$\frac{\partial I}{\partial \eta_A} = -\frac{\left\{ \eta^r f_{y^f} f_{y^p} + (1-2\eta_A)\xi \right\}}{\eta^{r2} f_{y^f}{}^2 f_{y^p}{}^2} \left(\frac{1+\frac{\phi}{\eta^p}}{1+\frac{\theta}{\varepsilon^p}} \right) >=< 0$$

$$\frac{\partial I}{\partial |\eta^r|} = \frac{\eta_A \left\{ 2\xi(1-\eta_A) + f_{y^f} f_{y^p} |\eta^r| \right\}}{f_{y^f}{}^2 f_{y^p}{}^2 |\eta^r|^3} \left(\frac{1+\frac{\phi}{\eta^p}}{1+\frac{\theta}{\varepsilon^p}} \right) >=< 0$$

$$\frac{\partial I}{\partial\left|\eta^{p}\right|}=-\frac{\eta_{A}}{\eta_{r}}\frac{1}{f_{y^{f}}f_{y^{p}}}\left(1+\frac{\xi}{H}\right)\left(\frac{\frac{\phi}{\left|\eta^{p}\right|^{2}}}{1+\frac{\theta}{\varepsilon^{p}}}\right)>0$$

$$\frac{\partial I}{\partial\varepsilon^{p}}=-\frac{\eta_{A}}{\eta_{r}}\frac{\theta}{\varepsilon^{p2}}\frac{1}{f_{y^{f}}f_{y^{p}}}\left(1+\frac{\xi}{H}\right)\left\{\frac{1+\frac{\phi}{\eta^{p}}}{\left(1+\frac{\theta}{\varepsilon^{p}}\right)^{2}}\right\}>0$$

$$\frac{\partial I}{\partial\left|H\right|}=-\frac{\eta_{A}}{\eta^{r}}\frac{1}{f_{y^{f}}f_{y^{p}}}\left(\frac{\xi}{\left|H\right|^{2}}\right)\left(\frac{1+\frac{\phi}{\eta^{p}}}{1+\frac{\theta}{\varepsilon^{p}}}\right)>0$$

$$\frac{\partial I}{\partial f_{y^{f}}}=\frac{\eta_{A}\left(2\xi\left(1-\eta_{A}\right)+f_{y^{f}}f_{y^{p}}\eta^{r}\right)}{f_{y^{f}}{}^{3}f_{y^{p}}{}^{2}\eta^{r2}}\left(\frac{1+\frac{\phi}{\eta^{p}}}{1+\frac{\theta}{\varepsilon^{p}}}\right)>=<0$$

$$\frac{\partial I}{\partial f_{y^{p}}}=\frac{\eta_{A}\left(2\xi\left(1-\eta_{A}\right)+f_{y^{f}}f_{y^{p}}\eta^{r}\right)}{f_{y^{f}}{}^{2}f_{y^{p}}{}^{3}\eta^{r2}}\left(\frac{1+\frac{\phi}{\eta^{p}}}{1+\frac{\theta}{\varepsilon^{p}}}\right)>=<0$$

$$\frac{\partial I}{\partial\xi}=-\frac{\eta_{A}}{\eta^{r}}\frac{1}{f_{y^{f}}f_{y^{p}}}\frac{1}{H}\left(\frac{1+\frac{\phi}{\eta^{p}}}{1+\frac{\theta}{\varepsilon^{p}}}\right)<0$$

$$\frac{\partial I}{\partial\phi}=-\frac{\eta_{A}}{\eta^{r}}\frac{1}{f_{y^{f}}f_{y^{p}}}\frac{1}{\eta^{p}}\left(1+\frac{\xi}{H}\right)\left(\frac{1}{1+\frac{\theta}{\varepsilon^{p}}}\right)<0$$

$$\frac{\partial I}{\partial\theta}=\frac{\eta_{A}}{\eta^{r}}\frac{1}{f_{y^{f}}f_{y^{p}}}\frac{1}{\varepsilon^{p}}\left(1+\frac{\xi}{H}\right)\left\{\frac{1+\frac{\phi}{\eta^{p}}}{\left(1+\frac{\theta}{\varepsilon^{p}}\right)^{2}}\right\}<0$$