Optimal Generic Advertising under Bilateral Imperfect Competition between Processors and Retailers

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Abstract

The purpose of this paper is to examine the impact of bilateral imperfect competition between processors and retailers and of import supply on optimal advertising intensity, advertising expenditures, and checkoff assessment rates. First, comparative static analyses were conducted on the newly developed optimal advertising intensity formula. Second, to consider the endogenous nature of optimal advertising, a linear market equilibrium model was developed and applied to the U.S. beef industry. Results showed that the full consideration of retailer-processor bilateral market power lowered the optimal values of assessment rates, advertising expenditures, and advertising intensity for the checkoff board while consideration of importers increases the optimal values. The results indicate that ignoring the import sector in optimal generic advertising modeling should underestimate these optimal values, while ignoring the bilateral market power between processors and retailers overestimates the values.

Key words: bilateral market power, checkoff, import supply, oligopoly, oligopsony, optimal advertising, processor, retailer

[EconLit citations: L13, L66, M37]

Agricultural producers have invested over $750 million annually into self-financed "checkoff" programs designed to increase their profits for various commodities. These checkoff programs have a long history dating back to the late 1800s with the creation of state-level voluntary programs to promote farm commodities. Since the mid-1980s, many state-level checkoff programs have been expanded to federally-legislated mandatory programs. These mandated programs require producers to pay a specified amount of money through either per unit or value assessment. For example, the dairy checkoff program that funds the well-known advertising campaign, "got milk" mandates all dairy farmers to pay fifteen cents per hundredweight of all milk marketed. The pork program that sponsors the "Pork: the Other White Meat" campaign specifies a mandatory assessment rate of 0.40 percent of sales value.

The specified checkoff assessment rates raise several important questions, particularly related to how they are determined and whether they can generate profit-maximizing advertising expenditures. Some producer groups are concerned that the current assessment is too small to produce significant advertising effects for their industry and is probably not profit maximizing. For example, in the summer of 2006, a task force team co-chaired by the National Cattlemen's Beef Association and the American Farm Bureau Federation evaluated the beef checkoff program and recommended an adjustment of the checkoff rate from the current one dollar to two dollars per head (Farm Futures, 2006). The committee recognized that the total beef chcekoff collection has been continuously declining, and as a result, the advertising expenditures have also been declining. In fact, the advertising expenditure for the beef industry peaked in 1990 at 33 million dollars, but since then, it has been continuously decreasing and was down to 18

million dollars in 2011 (Figure 1). Figure 1 also shows that the declining trend is even more noticeable when the expenditures are deflated by Media Cost Index (MCI) and Consumer Price Index (CPI).

Numerous studies have examined the optimality of advertising expenditures in both economics and agricultural economics literature (Dorfman and Steiner, 1954; Nerlove and Waugh, 1961; Goddard and McCutcheon, 1993; Zhang and Sexton, 2002; Kinnucan, 2003). One central issue in these studies is to determine the condition of optimal advertising intensity. The well-known Dorfman and Steiner (DS) Theorem (1954) shows that the optimality condition for joint price and advertising expenditure is characterized by the equality of the ratio of advertising (A) to sales (PQ), (where 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 ($|\eta_P|$), i.e., $\frac{\eta_A}{|\eta_P|} = \frac{A}{PQ}$.

Goddard and McCutcheon (GM) (1993) follow a similar framework to DS but allow both price and quantity to vary in response to the effective advertising. GM 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 the previous two studies, Nerlove and Waugh (NW) (1961) assume that producers have alternatives for the use of collected funds spent on advertising. In previous studies, the first order condition for the producer's profit maximization condition with respect to advertising equals zero. However, recognizing alternative uses of these funds such as buying government bonds, NW equate the marginal returns to the rate of returns on alternative forms of investment (ρ). NW also assume the supply response to advertising. Then, the corresponding

optimal advertising condition becomes $\frac{\eta_A}{(\varepsilon - \eta_P)(1+\rho)} = \frac{A}{PQ}$, where ε is the supply elasticity. Including the three studies reviewed so far, most studies in generic advertising literature derive the optimality condition under the competitive market structure. However in recent years, as food processing and retailing sectors have become increasingly concentrated, several studies have found the existence of imperfect competition in these sectors (Paul, 2001; Lopez, Azzam, and Espana, 2002; Chung and Tostao, 2009; Chung and Tostao, 2012).

To reflect the change in market structure in food processing and retailing sectors, Zhang and Sexton (ZS) (2002) and Kinnucan (2003) consider imperfect competition in deriving the optimality condition of advertising. ZS investigate the optimal conditions of generic advertising for agricultural markets where the downstream market exhibits oligopoly and oligopsony power. The optimal condition derived by ZS shows that unless advertising makes the demand more elastic, downstream oligopoly power reduces the optimal advertising intensity below the level specified by DS. Simulation results show that the producer checkoff rate increases as a function of the degree of oligopoly power in the downstream market while it decreases under its oligopsony power or joint oligopoly and oligopsony power. Kinnucan (2003) also investigates the impact of food industry market power on producers' optimal advertising level, but focuses on the assumption of technology for the food processing industry. His study assumes that food industry technology is characterized by variable proportions while possessing market power. Kinnucan concludes that market power tends to reduce the optimal level of advertising, but the reduction is moderated by factor substitution.

Although some studies, including ZS and Kinnucan (2003), derive the optimal advertising intensities under imperfectly competitive markets, these studies tend to focus on imperfect competition in the processing sector alone or at best in an integrated processing/retailing sector. No study accounts for the retailer's potential market power separately from processor's market power in deriving the optimal conditions of advertising intensity. Recent studies on the retailer-processor relationship find that retailers exercise a larger influence in food distribution than do processors (Digal and Ahmadi-Esfahani, 2002; Villas-Boas, 2007; Chung and Tostao, 2012). The existence of slotting and promotional fees to processors in many retailer chains is also evidence of retailers exercising market power over processors (Shaffer, 1991).

Another important issue in determining the optimal advertising intensity is considering import sector. Most studies have ignored the potential effect of importer behavior when deriving optimality condition for generic advertising programs. However, U.S. consumers consume significant amounts of imported agricultural commodities, which are also assessed for checkoff programs. For instance, approximately 8% and 4% of beef and pork marketed in the U.S. are imported (USDA, 2011a; USDA, 2011b), and importers also pay the checkoff assessment as domestic producers do. Imported dairy products account for about 2% of total U.S. dairy consumption (USDA, 2011c), and starting from August, 2011, importers of all dairy-based products are required to pay 7.5 cents per hundredweight while domestic producers pay 15 cents. The import data indicate that ignoring import supply may lead to incorrect optimal advertising intensity, and therefore, incorrect optimal advertising expenditures and assessment rates.

Objectives of this study are to derive an optimal advertising intensity formula that considers bilateral imperfect competition between processors and retailers and the supply of imported goods and to examine the impact of these unique features of derivation on optimal advertising intensity, advertising expenditures, and checkoff assessment rates. Unlike many previous studies, we model retailing and processing sectors separately and consider the processors' interaction effect with retailers in deriving the optimal advertising rule. Our approach relies on market equilibrium conditions and a combined pricing rule derived from first-order conditions of two separate profit maximization problems for a retailer and a processor and thus takes into account both upstream and downstream competitions in retail and processing sectors. For most checkoff programs, boards make decisions on the level of advertising expenditures based on estimated funds to be collected, but effective advertising programs induce changes in industry sales which affect the collected checkoff funds and, in turn, the money available for advertising. Therefore in this case, the advertising expenditures are endogenously determined by market equilibrium (Kinnucan and Myrland, 2000; Zhang and Sexton, 2002). The market equilibrium conditions of our approach include the endogenous nature in determining optimal advertising expenditures. To further illustrate the impact of bilateral market power (between processors and retailers) and importer behavior on the optimal level of advertising expenditures, we also develop a market equilibrium model that consists of retail demand, processor and import supply, and farm supply functions. The market equilibrium model is simulated with various levels of market power parameters, holding all other market parameters constant. The model is also applied to the U.S. beef industry to obtain optimal advertising intensity, advertising expenditure, and assessment

rate, and the results are compared to previous approaches that do not consider bilateral imperfect competition and import sector. Monte Carlo simulations are conducted to construct confidence intervals for sensitivity analyses of the results and comparisons of their mean differences.

Derivation of Optimal Advertising Intensity

In deriving the optimal advertising intensity, we extend previous studies, in particular, Zhang and Sexton (2002) and Kinnucan (2003), in two ways. First, we develop a model that allows retailer's oligopoly and oligopsony power separately from processor's market power. To allow the market power at retail and processing sectors separately, retailer and processor profit maximization problems are solved sequentially, and the profit maximization conditions are incorporated in a multi-equation model. Secondly, the new framework also considers import effects in determining optimal generic advertising intensity. To consider the import effects in our derivation, we include the import supply equation and the identity condition that equates retail demand with domestic supply plus import supply.

Therefore, our new framework includes equilibrium conditions of each production stage with consideration of trade and potential bilateral market power from retailers and processors. Our approach first defines a set of market equilibrium conditions and derives marginal effects of a change in assessment rate on equilibrium prices and quantities. Then, the optimal advertising intensity is determined from the derived marginal effects using the condition of checkoff board surplus maximization.

Consider a three-sector model where retailing and processing sectors are imperfectly competitive in both raw material and output markets, and the farm sector is

perfectly competitive in the output market. In this framework, retailers and processors exercise oligopsony power when procuring their raw materials while they also exercise oligopoly power in selling their products. Let $Y = Y^d + Y^m$, where Y is the aggregate quantity available at retail level, Y^d is domestic production, and Y^m is the quantity imported. Assuming constant return to scale in the food processing technology and fixed proportions with Leontief coefficient 1 in converting from farm to retail products leads to $Y^d = Y^p = Y^f$, where Y^p and Y^f are aggregate product quantities at processing and farm level, respectively.[1] We also define the advertising expenditure (A) as: $A = tY$, assuming all collected money is utilized for advertising, and t is the per-unit tax on domestic production and imports. Then, when p^r, p^p, and p^f are prices at retail, processing, and farm level, the market equilibrium can be expressed as the following set of equations:

(1) $Y = D[P^r, A(t)]$, retail demand,

(2) $Y^d = S^d(P^f, t)$, domestic supply,

(3) $Y^m = S^m(P^r, t)$, import supply,

(4) $Y = Y^d + Y^m$, identity condition,

(5) $A = tY(Y^d, Y^m)$, advertising expenditure.

Considering n^r identical retailers, i.e., $Y = n^r y^r$, we have a representative retailer's profit maximization problem as:

$$Max \quad \underset{y^r}{\pi} = P^r(Y,t)y^r - [P^p(Y_s^p) + m]y^r ,$$

where y^r and m represent finished product sales and constant marketing cost per unit for the representative retailer, respectively. The first order condition to the retailer's problem with respect to y^r leads to:

(6) $$P^r(Y,t)(1+\frac{\xi}{H(Y,t)}) = P^p(Y^p)(1+\frac{\omega}{\varepsilon_p^s}) + m,$$

where $\xi = (\partial Y \ / \partial y^r)(y^r / Y \ )$ and $\omega = (\partial Y^p / \partial y^r)(y^r / Y^p)$ are conjectural elasticities reflecting the degree of competition among retailers in selling finished products (ξ) and procuring processed products (ω), respectively;

$H(Y,t) = (dY / dP^r)(P^r / Y) = \eta_P /(1-\eta_A)$ and $\varepsilon_p^s = (dY_s^p / dP^p)(P^p / Y_s^p)$ are total price elasticity of demand and elasticity of processor supply, respectively.

Considering n^p identical processors, i.e., $Y^P = n^p y^p$, a representative processors' profit maximization problem is:

$$Max \quad \underset{y^p}{\pi} = P^p(Y_d^p)y^p - [W^P(Y^f,t) + c]y^p,$$

where y^p and c represent processed product sales to retailers and the constant processing cost per unit for the representative processor, respectively; and W^P is the price paid by processors to producers, and the relationship between W^P and P^f is represented by $W^p = P^f + t$. The first order condition of the processor's problem can be written in elasticity form as:

(7) $$P^p(Y^p,t)(1+\frac{\phi}{\varepsilon_p^d}) = P^f(Y^f,t)(1+\frac{\theta}{\varepsilon_f^s}) + t + c,$$

where the conjectural elasticity, $\phi = (\partial Y^p / \partial y^p)(y^p / Y^p)$ and $\theta = (\partial Y^f \ / \partial y^p)(y^p \ / Y^f)$ represent degree of competition among processors in selling processed products (ϕ) and procuring farm products (θ), respectively; $\varepsilon_P^d = (dY_d^p / dP^p)(P^p / Y_d^p)$ and $\varepsilon_f^s = (dY^f / dP^f)(P^f / Y^f)$ are the elasticity of derived demand at processor level and the supply elasticity at farm level, respectively. Substituting equation (6) in equation (7)

results in:

(8) $$P^r(Y,t)(1+\frac{\xi}{H(Y,t)}) = \frac{1}{1+\phi/\varepsilon_p^d}[(1+\frac{\theta}{\varepsilon_f^s})P^f(Y^f,t)+t+c](1+\frac{\varpi}{\varepsilon_p^s})+m.$$

Totally differentiating equations (1), (2), (3), (4), and (8) with respect to *t* results in:

(9) $$\frac{dY}{dt} = \frac{\partial D}{\partial P^r}\frac{dP^r}{dt}+\frac{\partial D}{\partial A}\frac{dA}{dt} = \frac{\partial D}{\partial P^r}\frac{dP^r}{dt}+\frac{\partial D}{\partial A}[Y(Y^d,Y^m)+t(\frac{dY^d}{dt}+\frac{dY^m}{dt})],$$

(10) $$\frac{dY^d}{dt} = \frac{\partial S^d}{\partial P^f}\frac{dP^f}{dt},$$

(11) $$\frac{dY^m}{dt} = \frac{\partial S^m}{\partial P^r}\frac{dP^r}{dt},$$

(12) $$\frac{dY}{dt} = \frac{dY^d}{dt}+\frac{dY^m}{dt},$$

(13) $$(1+\frac{\xi}{H(Y,t)})\frac{dP^r}{dt}-\frac{\xi P^r}{H^2}\frac{dH}{dt} = -\frac{1}{(1+\phi/\varepsilon_P^d)^2}\frac{\phi}{(\varepsilon_P^d)^2}\frac{d\varepsilon_P^d}{dt}[(1+\frac{\theta}{\varepsilon_f^s})P^f+t+c](1+\frac{\varpi}{\varepsilon_p^s})$$

$$+[(1+\frac{\theta}{\varepsilon_f^s})\frac{dP^f}{dt}-\frac{\theta P^f}{(\varepsilon_f^s)^2}\frac{d\varepsilon_f^s}{dt}+1](1+\frac{\varpi}{\varepsilon_p^s})(\frac{1}{1+\phi/\varepsilon_p^d})-(\frac{1}{1+\phi/\varepsilon_p^d})[(1+\frac{\theta}{\varepsilon_f^s})P^f+t+c]\frac{\varpi}{(\varepsilon_p^s)^2}\frac{d\varepsilon_p^s}{dt}.$$

Equation (13) can be rewritten in elasticity form as:

(13′) $$(1+\frac{\xi}{H(Y,t)})\frac{dP^r}{dt}-\frac{1}{1+\phi/\varepsilon_p^d}(1+\frac{\varpi}{\varepsilon_p^s})(1+\frac{\theta}{\varepsilon_f^s})\frac{dP^f}{dt}$$
$$= -\frac{1}{(1+\phi/\varepsilon_P^d)^2}\frac{\phi E_{\varepsilon_P^d,t}}{t\varepsilon_P^d}[(1+\frac{\theta}{\varepsilon_f^s})P^f+t+c](1+\frac{\varpi}{\varepsilon_p^s})$$
$$+(-\frac{\theta P^f}{t\varepsilon_f^s}E_{\varepsilon_f^s,t}+1)](1+\frac{\varpi}{\varepsilon_p^s})(\frac{1}{1+\phi/\varepsilon_p^d})-(\frac{1}{1+\phi/\varepsilon_p^d})[(1+\frac{\theta}{\varepsilon_f^s})P^f+t+c]\frac{\varpi}{t\varepsilon_p^s}E_{\varepsilon_P^s,t}$$
$$+\frac{\xi P^r}{Ht}E_{H,t},$$

where $E_{\varepsilon_P^d,t} = \frac{d\varepsilon_p^d}{dt}\frac{t}{\varepsilon_p^d}$, $E_{\varepsilon_P^s,t} = \frac{d\varepsilon_p^s}{dt}\frac{t}{\varepsilon_p^s}$, and $E_{\varepsilon_f^s,t} = \frac{d\varepsilon_f^s}{dt}\frac{t}{\varepsilon_f^s}$. $E_{\varepsilon_p^d,t}$, $E_{\varepsilon_p^s,t}$, and $E_{\varepsilon_f^s,t}$

represent the percentage change in elasticities of processors' derived demand and supply, and the elasticity of farm supply in response to one percent change in checkoff assessment rate t, respectively. $E_{H,t}$ represents the percentage change in total demand elasticity H in response to one percent change in advertising assessment t.

Equations (9), (10), (11), (12), and (13′) can be rewritten in matrix form as:

$$(14)\quad \begin{bmatrix} 1 & -\frac{\partial D}{\partial P} & -t\frac{\partial D}{\partial A} & -t\frac{\partial D}{\partial A} & 0 \\ 0 & 0 & 1 & 0 & -\frac{\partial S^d}{\partial P^f} \\ 0 & -\frac{\partial S^m}{\partial P^r} & 0 & 1 & 0 \\ 1 & 0 & -1 & -1 & 0 \\ 0 & 1+\frac{\xi}{H} & 0 & 0 & \frac{-(1+\frac{\varpi}{\varepsilon_p^s})(1+\frac{\theta}{\varepsilon_f^s})}{1+\phi/\varepsilon_p^d} \end{bmatrix} \begin{bmatrix} \frac{dY}{dt} \\ \frac{dP^r}{dt} \\ \frac{dY^d}{dt} \\ \frac{dY^m}{dt} \\ \frac{dP^f}{dt} \end{bmatrix} = \begin{bmatrix} \frac{\partial D}{\partial A}Y \\ 0 \\ 0 \\ 0 \\ \Omega \end{bmatrix},$$

where

$$\Omega = -\frac{1}{(1+\phi/\varepsilon_p^d)^2}\frac{\phi E_{\varepsilon_P^d,t}}{t\varepsilon_p^d}[(1+\frac{\theta}{\varepsilon_f^s})P^f + t + c](1+\frac{\varpi}{\varepsilon_P^s})$$

$$+(-\frac{\theta P^f}{t\varepsilon_f^s}E_{\varepsilon_f^s,t}+1)(1+\frac{\varpi}{\varepsilon_p^s})(\frac{1}{1+\phi/\varepsilon_p^d}) - (\frac{1}{1+\phi/\varepsilon_p^d})[(1+\frac{\theta}{\varepsilon_f^s})P^f + t + c]\frac{\varpi}{t\varepsilon_p^s}E_{\varepsilon_p^s,t} + \frac{\xi P^r}{Ht}E_{H,t}.$$

In previous studies (Alston, Carman, and Chalfant, 1994; Zhang and Sexton, 2002), a producer group's surplus maximization problem is considered to decide the per-unit assessment rate (t), and consequently generic advertising expenditures (A) for deriving an optimal generic advertising rule. The previous derivations do not take into account importer's surplus maximization. However, many commodity checkoff boards include importers as their members and therefore need to also consider importers' benefits when deciding the optimal per unit assessment rate (t). To account for both

domestic producer's and importer's surplus maximizations, we derive an optimal assessment condition from the first-order-condition of a combined producer-importer surplus maximization problem as:

$$\text{(15)} \qquad \frac{\partial Y^*}{\partial t} = \frac{\partial Y^{d*}}{\partial t} + \frac{\partial Y^{m*}}{\partial t} = 0.$$

Equation (15) suggests that the optimal assessment can be determined when the combined equilibrium quantity no longer changes even if the assessment rate changes. Applying the optimality condition, equation (15), to matrix (14), we have:

$$\text{(16)} \qquad \frac{1}{\Psi}\left[\begin{array}{l}\left[\Omega t\frac{\partial D\partial S^m}{\partial A\partial P^r} - \Omega\frac{\partial S^m}{\partial P^r} + \left(1+\frac{\xi}{H}\right)\frac{\partial D}{\partial A}Y + \Omega\frac{\partial D}{\partial P^r}\right]\frac{\partial S^d}{\partial P^f} \\ + \left[\Omega\frac{\partial S^d}{\partial P^f} - \frac{\Omega t\partial D\partial S^d}{\partial P^f\partial A} + \frac{\left(1+\frac{\varpi}{\varepsilon_p^s}\right)\left(1+\frac{\theta}{\varepsilon_f^s}\right)}{1+\frac{\phi}{\varepsilon_p^d}}\frac{\partial D}{\partial A}Y\right]\frac{\partial S^m}{\partial P^r}\end{array}\right] = 0,$$

where

$$\Psi = \frac{\left(1+\frac{\varpi}{\varepsilon_p^s}\right)\left(1+\frac{\theta}{\varepsilon_f^s}\right)}{\left(1+\frac{\phi}{\varepsilon_p^d}\right)}\left(\frac{\partial S^m}{\partial P^r} - t\frac{\partial D\partial S^m}{\partial A\partial P^r} - \frac{\partial D}{\partial P^r}\right) + \frac{\partial S^d}{\partial P^f}\left(1+\frac{\xi}{H}\right)\left(1-t\frac{\partial D}{\partial A}\right).$$

Rewriting equation (16) in an elasticity form and rearranging it results in the optimal advertising intensity (I^*) as:

$$\text{(17)} \qquad \frac{A^*}{P^{r*}Y^*} = I^* = \left[-\frac{\eta_A}{\eta_p}\left(1+\frac{\xi}{H}\right) - \frac{\xi}{H}E_{H,t}\right]\frac{\left(1+\frac{\phi}{\varepsilon_p^d}\right)}{\left(1+\frac{\varpi}{\varepsilon_p^s}\right)} - \frac{\eta_A\eta_m\tau}{\eta_p\varepsilon_f^s}\left(1+\frac{\theta}{\varepsilon_f^s}\right)\left[\frac{f^f}{(1-\tau)^2}\right],$$

where $\eta_m = \frac{\partial S^m}{\partial P^r}\frac{P^r}{S^m}$ is the import supply elasticity, $\tau = \frac{S^m}{Y}$ is the import share from total consumption, and f^f is the producer share from total retailer revenue, i.e.,

$$f^f = \frac{P^f Y^f}{P^r Y} = (1-\tau)\frac{P^f}{P^r}.$$ [2]

Equation (17) shows that the optimal advertising intensity (advertising to retailer sales ratio) now depends on not only advertising and demand elasticities of retailers, but also retailers' and processors' bilateral market power parameters, demand and supply elasticities of processors, elasticity of farm supply, and import supply elasticity. Unlike previous studies, the newly derived advertising intensity equation clearly shows that the bilateral market power relationship between processors and retailers (both oligopoly and oligopsony powers of retailers and processors) plays an important role in determining the optimal advertising intensity when the processing sector is considered separately from a combined processing-retailing sector. The advertising intensity derived by Zhang and Sexton (2002) shows no direct effect of oligopsony power from the retailer-processing sector. However, when the processing sector is considered separately from the retailing sector, and import sector is added to the model, all four bilateral market power parameters affect the optimal condition even if no advertising effect is assumed in changing the elasticity of processor demand and supply elasticities of farm and processing sectors. When the model allows advertising to change the elasticity of processor demand and supply elasticities of farm and processing sectors, the impact of bilateral market power between retailers and processors becomes even more extensive (see Appendix 1). Note that equation (17) can be reduced to the Zhang and Sexton's optimal advertising intensity rule when an integrated retail and processing sector is

assumed to exert its oligopoly and oligopsony market power, and import is restricted to zero.[3] Equation (17) can be further reduced to the Dorfman and Steiner's optimal advertising intensity condition when no market power in retailing and processing sectors and no import are considered.

Comparative Static Results for Optimal Advertising Intensity

Impacts of bilateral imperfect competition parameters and import supply elasticity on advertising intensity are examined via comparative statics on equation (17). Comparative static results are:

$$\frac{\partial I^*}{\partial \xi} = -\frac{1}{H}\left(E_{H,t} + \frac{\eta_A}{\eta_P}\right)\frac{\left(1+\frac{\phi}{\varepsilon_p^d}\right)}{\left(1+\frac{\varpi}{\varepsilon_p^s}\right)} >=< 0,$$

$$\frac{\partial I^*}{\partial \varpi} = \left[\frac{\eta_A}{\eta_p} + \frac{\xi}{H}\left(E_{H,t} + \frac{\eta_A}{\eta_p}\right)\right]\frac{\varepsilon_p^s(\varepsilon_p^d + \phi)}{\varepsilon_p^d(\varepsilon_p^s + \varpi)^2} >=< 0,$$

$$\frac{\partial I^*}{\partial \phi} = -\left[\frac{\eta_A}{\eta_p} + \frac{\xi}{H}\left(E_{H,t} + \frac{\eta_A}{\eta_p}\right)\right]\frac{\varepsilon_p^s}{\varepsilon_p^d(\varepsilon_p^s + \varpi)} >=< 0,$$

$$\frac{\partial I^*}{\partial \theta} = -\frac{\eta_A \eta_m \tau}{\eta_P(\varepsilon_f^s)^2}\frac{f^f}{(1-\tau)^2} > 0,$$

$$\frac{\partial I^*}{\partial \eta_m} = -\frac{\eta_A \tau}{\eta_P \varepsilon_f^s}\left(1+\frac{\theta}{\varepsilon_f^s}\right)\left[\frac{f^f}{(1-\tau)^2}\right] > 0.$$

The impact of changing retailer's oligopoly power on optimal advertising intensity, $\frac{\partial I^*}{\partial \xi}$, cannot be signed in general. However, under the condition $E_{H,t}$ <0 (increasing *t* and thus *A* induces higher consumer loyalty, therefore creating less elastic total demand elasticity) the optimal advertising intensity decreases as the retailer's oligopoly power increases.[4, 5] This result can be justified because the less elastic retail demand due to advertisements will increase oligopoly distortion, thereby providing less benefit to producers. Under the

condition $E_{H,t}$>0, the sign of $\frac{\partial I^*}{\partial \xi}$ depends on the sign of $E_{H,t} + \frac{\eta_A}{\eta_p}$. When $E_{H,t}$=0 (increasing *t* has no impact on changing the total demand elasticity) the board's optimal advertising intensity decreases with the retailer's oligopoly distortion. The board's profit maximizing advertising intensity decreases because the retailer's oligopoly distortion leads to decreased output and increased retail price. Effects of retailer's oligopsony and processor's oligopoly distortion, $\frac{\partial I^*}{\partial \omega}$ and $\frac{\partial I^*}{\partial \phi}$, in determining the optimal advertising intensity cannot be signed as well. Signs of $\frac{\partial I^*}{\partial \omega}$ and $\frac{\partial I^*}{\partial \phi}$ depend on signs of $\frac{\eta_A}{\eta_p} + \frac{\xi}{H}(E_{H,t} + \frac{\eta_A}{\eta_p})$. Zhang and Sexton (2002) show that processor oligopsony power does not affect the optimal advertising intensity under the condition that changing *t* (thereby *A*) does not affect changing the farm supply elasticity ($E_{\varepsilon_f^s,t} = 0$). However, the comparative static results in this article show that even with conditions, $E_{\varepsilon_f^s,t} = 0$ and $E_{\varepsilon_p^s,t} = 0$ (no supply elasticity change at both processor and farm levels due to advertising) the processor oligopsony power does affect the optimal intensity positively ($\frac{\partial I^*}{\partial \theta}$>0). The result reflects only the contribution of import sector to the intensity in response to the processor's oligopsony distortion. An increase in the processor's oligopsony power will decrease its purchase of domestic output and thus will increase import supply, which will benefit importers. Therefore, the increase in the processor's oligopsony distortion provides an incentive for importers to increase advertising intensity.

However, overall effect of $\frac{\partial I^*}{\partial \theta}$ should depend on signs of $E_{\varepsilon_f^s,t}$ and $E_{\varepsilon_p^s,t}$ in a fully extended model that does not impose the conditions, $E_{\varepsilon_f^s,t} = 0$ and $E_{\varepsilon_p^s,t} = 0$ (see Appendix 1). The impact of import supply elasticity on the optimal advertising intensity, $\frac{\partial I^*}{\partial \eta_m}$, is positive. The result indicates that an increase in import supply elasticity will incentivize importers to increase advertising expenditures, and therefore higher advertising intensity.

Market Equilibrium Model

Many comparative statics in the previous section were not able to be signed, and the comparative statics do not consider the fact that advertising decisions of many commodity checkoff programs are often tied to industry sales and therefore determined endogenously by market equilibrium. To address the limitation and better understand the impact of bilateral market power between processors and retailers and the consideration of import sector on the optimal level of advertising intensity, we construct a linear market equilibrium model that includes retail demand, processor and import supply, and farm supply functions. Therefore, it is important to note that the inferences of any results should be limited to the case of the linear model. The model includes the following three linear equations as:

(18) $Y = a + \mu\sqrt{A} - \alpha P^r$, Retail demand

(19) $P^p = b + \beta Y^p + \gamma Y^m$, Processor and import supply

(20) $P^f = d + \delta Y^f$, Farm supply,

where a, b, and d are intercept terms for each equation, and α, β, γ, δ, and μ are slope

coefficients of P^r, Y^p, Y^m, Y^f, and $\sqrt{A}$, respectively. In equation (18), the square root form of the advertising variable insures the concavity of retail demand in advertising. Since most of the imported red meat products are incorporated into the supply chain at the wholesale level and priced at wholesale value, import supply is included in equation (19) with processor supply.

To obtain market equilibrium prices and outputs, we apply linear equations (18) through (20) to the joint profit maximizing condition of retailer and processor in equation (8). For brevity and computational convenience, the competitive retail price and output without advertising are normalized at one. Therefore, all equilibrium solutions derived hereafter are relative to the competitive base values. Then, by imposing the normalized competitive values on the profit maximization conditions of retailer and processor, we have:

$$(21)\quad a=\alpha+1,\ b=1-c-\beta(1-\tau)-\gamma\tau,\ d=1-c-m-\delta(1-\tau)$$
$$\alpha=\eta_p,\ \beta=\frac{1}{\eta_m\tau},\ \gamma=\frac{f^p}{\varepsilon_p^s(1-\tau)^2},\ \delta=\frac{f^f}{\varepsilon_f^s(1-\tau)^2},\ f^p=(1-\tau)P^p,\ f^f=(1-\tau)P^f,$$

where f^p is the processor share of total retail revenue. Applying equations (18) to (21) to equation (8) and solving for Y results in:

$$(22)\quad Y^*=\left[\frac{(\phi-\xi-2)\mu\sqrt{t}-\sqrt{(\phi-\xi-2)^2\mu^2 t-16\Gamma\left(\frac{f^f\eta_p}{\varepsilon_f^s(1-\tau)}-1-\eta_p t\right)}}{4\Gamma}\right]^2,$$

where $\Gamma=(1+\xi)-(1+\theta)\frac{f^f\eta_p}{\varepsilon_f^s(1-\tau)}+\phi-\varpi\eta_p\left(\frac{f^p}{\varepsilon_p^s(1-\tau)}+\frac{1}{\eta_m}\right)$. Following equation (15), the board's optimal assessment, t^*, can be derived from equation (22) as:

$$(23) \quad t^* = \frac{\left(1 - \frac{f^f \eta_p}{\varepsilon_f^s (1-\tau)}\right)(\phi - \xi - 2)^2 \mu^2}{\eta_p [16\eta_p \Gamma + \mu^2 (\phi - \xi - 2)^2]}.$$

From equations (22) and (23), we can have checkoff board's optimal assessment rate, t^* and $A^* = t^* Y^*$. To be able to compute the optimal advertising intensity, the advertising-sales ratio, $I^* = \frac{A^*}{P^{r*} Y^*} = \frac{t^*}{P^{r*}}$, we need to compute optimal retail price P^{r*}. The optimal retail price with consideration of bilateral market power between retailer and processor can be obtained by substituting Y^* into equation (18).[6]

Simulation Results

The main purpose of the simulation is to examine the impact of bilateral market power on the optimal advertising conditions. Therefore, the parameterized optimality conditions, t^*, A^*, and I^*, are simulated with different levels of market power parameters while all other parameters in the solutions remain constant. Parameter values for these simulations are set at $\eta_A = 0.05$, $\eta_p = -1, \eta_m = \varepsilon_p^s = \varepsilon_f^s = 1$, $f^f = 0.5$ and $f^p = 0.6$. Simulation results are depicted in figures 2- 4. Figure 2 shows the impact of bilateral market power on optimal assessment rate, t^*. Zhang and Sexton (2002) report t^* increases as a function of oligopoly power exercised by an integrated retailing-processing sector. However, Figure 2 shows t^* increases only with retailer's oligopoly power while t^* decreases with all other market power parameters. Overall, t^* decreases as the joint bilateral market power between retailers and processors increases.

Figure 3 illustrates the impact of bilateral market power on the amount of optimal advertising, $A^* = t^* Y^*$. A^* decreases with all market power parameters. The optimal

advertising expenditure decreases even with retailer oligopoly power because the decrease in Y^* (due to the increased market power) outweighs the increase in t^* (see Figure 2). It is straightforward that A^* decreases with all other market power parameters because both t^* and Y^* decreases as these market power parameters increase.

The impact of bilateral market power on the optimal advertising intensity, $I^* = \frac{A^*}{P^{r*}Y^*} = \frac{t^*}{P^{r*}}$, is shown in Figure 4. I^* slightly decreases as retailer's oligopoly power increases because the increase in P^{r*} (due to the increased market power) offsets the increase in t^*. For all other market power parameters, the increase in market power decreases t^* and increases P^{r*}, which results in the decrease in I^*. In turn, when retailers and processors increase their market power in either the buying or selling side, or both, their profit-maximizing advertising intensity should decrease. Therefore, given that the optimal advertising decision is made via a linear market equilibrium model constructed in this section, overall the bilateral market power of retailing and processing sectors induces the decrease in the optimal assessment rate, advertising spending, and advertising intensity for the checkoff board. One exception is that the optimal assessment rate increases with the oligopoly power of the retailing sector.

Another purpose of the simulation is to investigate whether the newly developed procedure in this study produces different optimality conditions compared to alternative procedures when retailers' and processors' bilateral market powers and the role of importers are fully accounted. Four different models (including the one developed in this study) are considered, and optimal solutions (assessment rate, advertising expenditure, and advertising intensity) of each model are compared. Model I is a simple framework without considering market power and importers (similar to the assumption used for

Dorfman and Steiner, 1954) while Model II considers oligopoly and oligopsony power of an integrated processing-retailing sector (Zhang and Sexton, 2002) without importers ($\phi = \varpi = 0$ and $\eta_m = \tau = 0$). Model III takes into account full bilateral market power between retailers and processors but without importers ($\eta_m = \tau = 0$), and Model IV adds importers to Model III. The optimal solutions, t^*, A^*, and I^*, are computed using solutions of linear models (18) – (20) while imposing assumptions that are assigned for each model. Parameter values used for the computations are the same as those used for figures 2 to 4, except η_p = -0.45 (Brester and Wohlgenant, 1993) and ε_f^s = 0.15 (Wohlgenant, 1993) for the U.S. beef industry. We also set all market power parameters at 0.5. Since these parameter values are collected from previous studies, calculated from data, or assigned by authors, one could be concerned about sensitivity and statistical inferences of the optimal solutions. To address this issue, confidence intervals for each estimate are calculated using the Monte Carlo procedure suggested by Davis and Espinoza (1998) and Griffiths and Zhao (2000). First, 1,000 observations are randomly drawn from normal distribution for parameters while taking the selected values in the literature as most frequent values (η_A = 0.05, η_p = -0.45, ε_f^s = 0.15, τ = 0.08) with *p*-value of 0.05. Then, the 2.5th and 97.5th percentiles are calculated for lower and upper values of the 95 percent confidence intervals out of 1000 estimated values of t^*, A^*, and I^*. Another set of Monte Carlo simulations are conducted with gamma distribution to see if results are sensitive to assumptions on the distribution of parameters. The shape of gamma distribution is determined by two parameters, *k* and *v*, which are computed from mean = kv, and variance = kv^2. Means and variances of the four parameters remain the same as those used for the normal distribution.

Table 1 reports means and corresponding confidence intervals of optimal solutions computed with parameter values that were generated under the assumption of normal distribution. Results show that Model I (with no market power and no importers) results in the highest t^*, A^*, and I^*, while Model III (with full bilateral market power between retailing and processing sectors but with no importers) produces the lowest optimal values. Comparing results of Model I and Model II indicates that considering market power for an integrated retailer-processor industry clearly lowers the optimal values of assessment rates, advertising expenditures, and advertising intensity for the producer checkoff board. The optimal values become even smaller when we consider full bilateral market power for retailers and processors in both buying and selling markets in Model III.[7] The results are consistent with our findings from figures 2 to 4. Figures 2 to 4 showed that the increase in market power decreased t^*, A^*, and I^*. The only exceptional case was from retailer's oligopoly power, where t^* increased with the oligopoly power. However, when market powers were considered jointly, market power of retailers and processors always decreased the optimal values. Comparing results of Model III and Model IV shows that including importers in the model increases the optimal values. Note that Comparative static results discussed earlier also show $\frac{\partial I^*}{\partial \eta_m} > 0$, and a simple derivative from equation (17) leads to $\frac{\partial I^*}{\partial \tau} > 0$. The confidence intervals in table 1 indicate that all estimates are statistically significant at the 5 percent level.

Table 2 compares mean differences of optimal values computed from models I to IV and shows corresponding confidence intervals. Mean differences reported in the 2nd (I-II) and 3rd (I-III) row signify the importance of considering market power in estimating

optimal values, t^*, A^*, and I^*. All mean differences from these two rows are statically significant at the 5 % level except the difference in t^* between models I and II. The 4th row (I-IV) shows the differences are still statistically significant for A^* and I^* even if import sector is added to the full bilateral market power model. The 5th row (II-III) illustrates the importance of considering full bilateral market power between retailers and processors in estimating the optimal values. All differences in this row are statistically significant. The last row compares results between models III and IV, and differences in t^* and A^* are statistically significant at the 5% level. The test results demonstrate the importance of incorporating import sector in estimating the optimal values, t^* and A^*.

Tables 3 and 4 report means of the optimal values from models I – IV and mean differences of these values between the models with gamma distributed parameters. Optimal values with gamma distribution appear lower than those with normal distribution. However, our previous findings from tables 1 and 2 remain the same.[8] Therefore, tables 1 to 4 indicate that ignoring the import sector in generic advertising modeling should underestimate the optimal values of assessment rate, advertising expenditure, and advertising intensity, while ignoring the bilateral market power between processors and retailers overestimates these values.

Conclusions

This paper derived an optimal advertising model that considers bilateral imperfect competition between processors and retailers and the supply of imported goods and examined the impact of these unique features of derivation on optimal advertising intensity, advertising expenditures, and checkoff assessment rates. First, comparative static analyses were conducted on the newly developed optimal advertising intensity

formula to examine the impact of bilateral market power and import supply on the optimal advertising intensity. Second, a linear market equilibrium model that consists of retail demand, processor and import supply, and farm supply equations were developed to examine the impact of bilateral market power on the optimal advertising conditions. Solutions from the linear market equilibrium model were simulated with different levels of market power parameters while all other parameters in the solutions remain constant.

Finally, the linear equilibrium model was applied to the U.S. beef industry to obtain optimal conditions of generic advertising, and results were compared to previous approaches that did not consider bilateral imperfect competition and import sector. Monte Carlo simulations were conducted to construct confidence intervals for sensitivity analyses and statistical inferences of the results.

Impacts of changing bilateral market power parameters on advertising intensity could not be signed from comparative static analyses in general. One exception was that processor oligopsony power affected the optimal intensity positively when no supply elasticity change caused by advertising was assumed at both processor and farm levels. This finding is simply due to the contribution of the import sector to the intensity in response to the processor's oligopsony distortion. However, the overall impact of changing the processor oligopsony power on the optimal advertising intensity could be examined in a fully extended model without imposing any conditions on supply elasticity change at both processor and farm levels. The impact of import supply elasticity on the optimal advertising intensity was positive, which indicates that an increase in import supply elasticity leads to importer's higher incentive to advertising, and therefore, higher advertising intensity. Simulation results of a linear market equilibrium model showed

that overall the bilateral market power of retailing and processing sectors induced the decrease in optimal assessment rates, advertising spending, and advertising intensity for the checkoff board. One exception was that the optimal assessment rate increased with the oligopoly power of the retailing sector. Additional simulations were conducted to compare the newly developed procedure with previous approaches that did not consider bilateral imperfect competition and import sector. Comparing simulated estimates from alternative procedures showed that the full consideration of retailer and processor bilateral market power lowered the optimal advertising conditions while incorporating importers in the model increased the optimal values. The simulated optimal values from the new procedure were statistically different from those of previous procedures, in general, and appeared not too sensitive to the assumption of probability distribution on parameter values used in simulations. The simulation results signify the importance of considering the retailer/processor bilateral market power and import supply in determining optimal advertising conditions for commodity checkoff boards. Therefore, based on comparative static results and simulation results from a linear market equilibrium model, we conclude that optimal advertising conditions can be overestimated without fully considering the bilateral market power while they can be underestimated without import supply.

Footnotes

1. Clearly it is difficult to find an industry that satisfies these assumptions. However, as Sexton (2000) correctly states, these simplifying assumptions do not bias the analysis of competition in any particular direction and are made at no additional cost for generality.

2. Note that for brevity, we assume advertising has no impact on changing the elasticity of processor demand and elasticities of processor and producer supply (i.e., $E_{\varepsilon_p^d,t} = 0,$ $E_{\varepsilon_p^s,t} = 0,$ and $E_{\varepsilon_f^s,t} = 0,$) which is similar to previous studies (Alston, Carman, and Chalfant, 1994; Zhang and Sexton, 2002; Kinnucan, 2003). The derivation for the case where $E_{\varepsilon_p^d,t} \neq 0,$ $E_{\varepsilon_p^s,t} \neq 0$, and $E_{\varepsilon_p^s,t} \neq 0$ is reported in Appendix 1.

3. More specifically, equation (17) is reduced to the Zhang and Sexton's advertising-sales ratio when $\phi = \varpi = 0$ (or $\varepsilon_p^d = \varepsilon_p^s = \infty$) and $\eta_m = \tau = 0$.

4. From equation (7), $\left(1 + \frac{\phi}{\varepsilon_p^d}\right) > 0$.

5. In the advertising literature, how advertising affects demand elasticity is unclear. One school of thought is 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 (Stigler, 1961; Nelsen, 1974; Eskin, 1975; Grossman and Shapiro, 1984). The other school 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 (Bain, 1956; Comanor and Wilson 1979; Schmalensee, 1983).

6. The solution for P^{r*} is too long to present here. The solution can be provided upon request.

7. One could argue that since Model II represents an integrated processing-retailing sector, some portion of the market power parameters used in this model (ξ and θ) may be distributed to other bilateral market power parameters (ϕ and ϖ) considered in Model III and IV. To address this concern, we set the values of all market power parameters in Model III and IV at 0.25 while maintaining ξ and θ in Model II at 0.5. Results show that as expected, the optimal values from Model III and IV decrease (compared to those reported in tables 1 and 2), but they are still significantly lower than those of Model II.

8. As we did in footnote 7, separate simulations were conducted with gamma distribution to compute means and mean differences while setting the values of all market power parameters in Model III and IV at 0.25 and ξ and θ in Model II at 0.5. As we observed in footnote 7, overall findings remained the same under gamma distribution as well.

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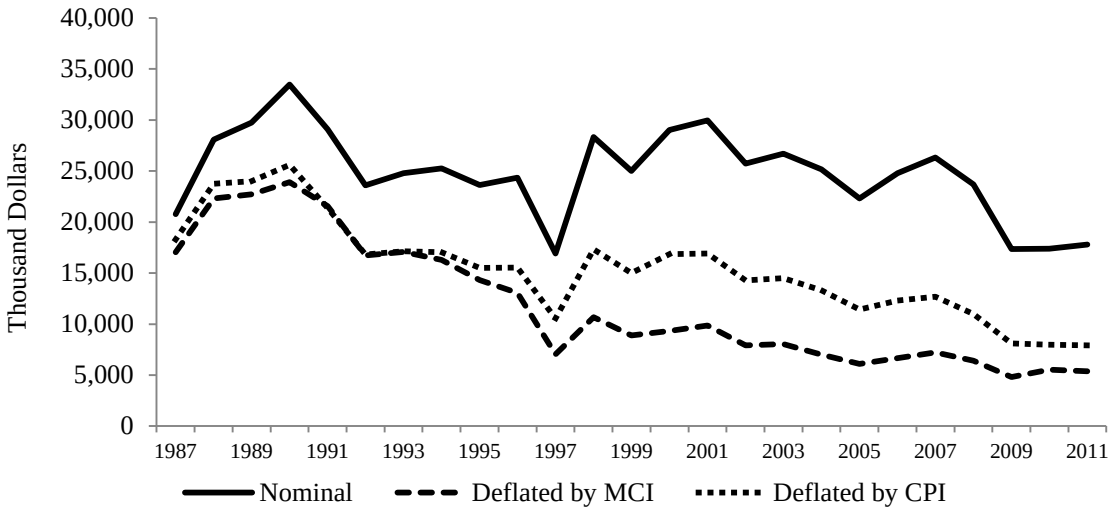

Figure 1. Generic Advertising Expenditures of U.S. Beef Industry for 1987 – 2011

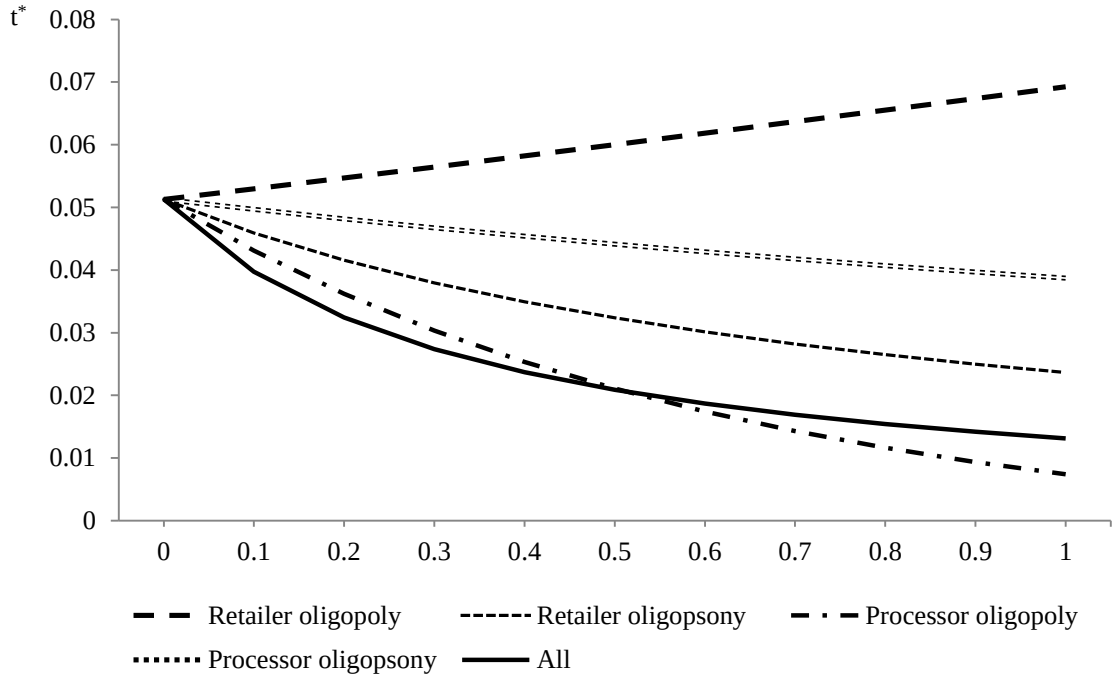

Figure 2. Impact of Bilateral Market Power on Optimal Assessment Rate (t^*)

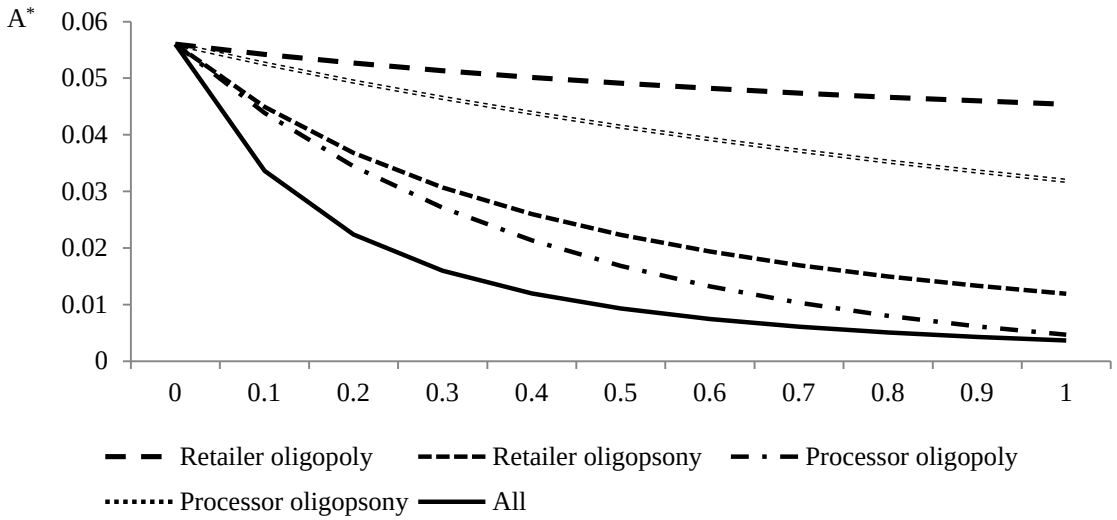

Figure 3. Impact of Bilateral Market Power on Optimal Advertising Expenditure (A^*)

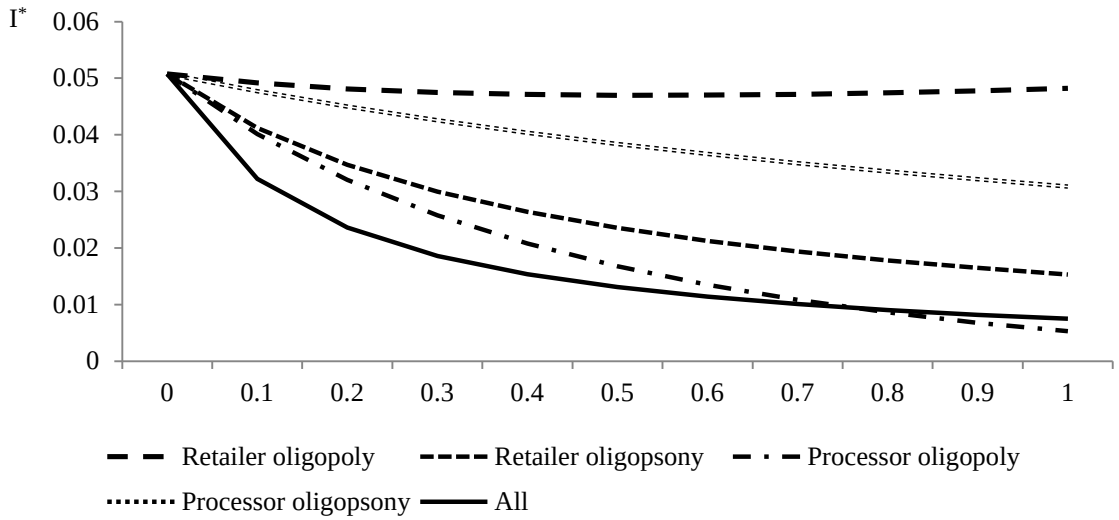

Figure 4. Impact of Bilateral Market Power on Optimal Advertising Intensity (I^*)

Table 1. Means of Optimal Assessment Rate, Advertising, and Advertising Intensity from Alternative Models with Normally Distributed Parameter Values

Model	t^*	A^*	I^*
I	0.1953^{**} (0.0153, 0.6789)	0.2020^{**} (0.0153, 0.7004)	0.1158^{**} (0.0149, 0.3627)
II	0.1494^{**} (0.0090, 0.4971)	0.1045^{**} (0.0056, 0.3314)	0.0518^{**} (0.0050, 0.1211)
III	0.0940^{**} (0.0060, 0.4358)	0.0571^{**} (0.0031, 0.1750)	0.0276^{**} (0.0033, 0.0691)
IV	0.1129^{**} (0.0063, 0.4358)	0.0706^{**} (0.0040, 0.2536)	0.0335^{**} (0.0033, 0.0846)

Numbers in parentheses are 95 percent confidence intervals.
**Significant at the 5% level.

Table 2. Differences between Means of Optimal Assessment Rate, Advertising, and Advertising Intensity from Alternative Models with Normally Distributed Parameter Values

Mean difference	t^*	A^*	I^*
I-II	0.0459 (-0.0055, 0.1941)	0.0975^{**} (0.0031, 0.3713)	0.0690^{**} (0.0044, 0.2661)
I-III	0.1011^{**} (0.0060, 0.3793)	0.1448^{**} (0.0100, 0.5591)	0.0882^{**} (0.0099, 0.3252)
I-IV	0.0824 (-0.0032, 0.3659)	0.1318^{**} (0.0053, 0.5388)	0.0823^{**} (0.0051, 0.3582)
II-III	0.0554^{**} (0.0006, 0.2088)	0.0459^{**} (0.0006, 0.1899)	0.0242^{**} (0.0006, 0.0625)
III-IV	-0.0189^{**} (-0.0753, -0.0012)	-0.0132^{**} (-0.0393, -0.0025)	-0.0059 (-0.0180, 0.0056)

Numbers in parentheses are 95 percent confidence intervals.
**Significant at the 5% level.

Table 3. Means of Optimal Assessment Rate, Advertising, and Advertising Intensity from Alternative Models with Gamma Distributed Parameter Values

Model	t^*	A^*	I^*
I	0.1283^{**} (0.3172, 0.3239)	0.1320^{**} (0.0319, 0.3374)	0.1018^{**} (0.0301, 0.2200)
II	0.0854^{**} (0.0203, 0.2304)	0.0545^{**} (0.0116, 0.1533)	0.0424^{**} (0.0132, 0.0968)
III	0.0515^{**} (0.0110, 0.1546)	0.0294^{**} (0.0056, 0.0909)	0.0245^{**} (0.0065, 0.0571)
IV	0.0755^{**} (0.0175, 0.2033)	0.0387^{**} (0.0084, 0.1101)	0.0328^{**} (0.0100, 0.0703)

Numbers in parentheses are 95 percent confidence intervals.
**Significant at the 5% level.

Table 4. Differences between Means of Optimal Assessment Rate, Advertising, and Advertising Intensity from Alternative Models with Gamma Distributed Parameter Values

Mean difference	t^*	A^*	I^*
I-II	0.0429^{**} (0.0064, 0.1224)	0.0775^{**} (0.0162, 0.2066)	0.0586^{**} (0.0140, 0.1411)
I-III	0.0742^{**} (0.0166, 0.1910)	0.1026^{**} (0.0236, 0.2650)	0.0773^{**} (0.0207, 0.1728)
I-IV	0.0528^{**} (0.0066, 0.1547)	0.0934^{**} (0.0207, 0.2489)	0.0690^{**} (0.0167, 0.1636)
II-III	0.0339^{**} (0.0055, 0.0898)	0.0296^{**} (0.0042, 0.0764)	0.0178^{**} (0.0040, 0.0451)
III-IV	-0.0213^{**} (-0.0530, -0.0005)	-0.0092^{**} (-0.0254, -0.0010)	-0.0083^{**} (-0.0183, -0.0017)

Numbers in parentheses are 95 percent confidence intervals.
**Significant at the 5% level.

Appendix 1.

Advertising intensity with $E_{\varepsilon_p^d,t} \neq 0$, $E_{\varepsilon_p^s,t} \neq 0$, and $E_{\varepsilon_f^s,t} \neq 0$ is derived as:

$$\frac{A^*}{P^*Y^*} = \frac{1}{\Phi}\left[\begin{array}{l} \left(\dfrac{f^f\left(1+\dfrac{\theta}{\varepsilon_f^s}\right)\left(1+\dfrac{\varpi}{\varepsilon_p^s}\right)}{(1-\tau)}\left(E_{\varepsilon_{p,t}^s}(\phi+\varpi) - \dfrac{\eta_A\eta_m\tau\left(1+\dfrac{\phi}{\varepsilon_p^d}\right)}{\eta_p\varepsilon_f^s(1-\tau)}\right)\right) \\ + \dfrac{\theta E_{\varepsilon_{f,t}^s} f^f\left(1+\dfrac{\varpi}{\varepsilon_p^s}\right)}{\varepsilon_f^s(1-\tau)} - \dfrac{\eta_A\left(1+\dfrac{\xi}{H}\right)\left(1+\dfrac{\phi}{\varepsilon_p^d}\right)^2}{\eta_p} \\ - \dfrac{\xi E_{H,t}\left(1+\dfrac{\phi}{\varepsilon_p^d}\right)^2}{H} - cE_{\varepsilon_{p,t}^d}\left(\phi\left(1+\dfrac{\varpi}{\varepsilon_p^s}\right)+\varpi\left(1+\dfrac{\phi}{\varepsilon_p^d}\right)\right) \end{array}\right]$$

where

$$\Phi = -\phi E_{\varepsilon_{p,t}^d}\left(1+\frac{\varpi}{\varepsilon_p^s}\right) + \left(1+\frac{\varpi}{\varepsilon_p^s}\right)\left(1+\frac{\phi}{\varepsilon_p^d}\right) - \varpi E_{\varepsilon_{p,t}^s}\left(1+\frac{\phi}{\varepsilon_p^d}\right)$$