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Revisiting Concentration in Food and Agricultural Supply Chains: The Welfare Implications of Market Power in a Complementary Input Sector

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Abstract

The use of complementary inputs is a key characteristic of the production process in many food related industries. In this article we explore how market power in a complementary input sector compares to the exertion of market power in a downstream sector for both producer and consumer welfare, as well as for policy. We develop a model of a homogenous product market that encompasses both bilateral and complementary relationships. The model focuses on the primary input sector and allows for exertion of market power by both complementary input suppliers and downstream firms. We use comparative statics analyses and numerical simulations to study the economic equilibrium under different scenarios of market power exertion. With respect to the welfare of primary input suppliers, our main finding is that market power exercised by the supplier of a complementary input generates greater negative effects than the same level of market power exercised by the downstream firms. We provide a discussion of the implications of the results for policy in the context of current problems within the Canadian grain handling and transportation system.

Keywords: Supply Chain Competitiveness, Complementary Sectors, Market Power, Grain Handling and Transportation System

JEL: D43, L13, Q13

High market concentration is a characteristic of many food industries in developed countries. Concentration has been observed in both downstream and complementary sectors of vertical food chains.[i] For example, in 2007, the average four-firm concentration ratio (CR4) for US food manufacturing industries was about 50%, while for livestock industries, the 2010 CR4 exceeded 85% for steers and heifers, and 65% for hog slaughter (Crespi, Saitone and Sexton 2012). In Europe the average CR4 in grocery retailing across the EU countries exceeds 50% (ECB Report, 2011).[ii] Similarly, as of 2010 the CR4 for primary grain handling capacity in Canada was approximately 72%, while the complementary rail industry serving the grain handling system is still characterized by most as a duopoly (Fulton, 2011).

These and other similar trends worldwide in agriculture raise concerns about whether downstream firms in fact exercise market power to the detriment of both producers and consumers. Accordingly, a large literature has been devoted to the analysis of market power in the processing/wholesale and retailing sectors of the food industry. But the implications of potential market power in complementary input sectors have not been explored. In this research, we fill this void by investigating the economic and welfare consequences stemming from the exercise of market power in a complementary input sector, compared to the economic and welfare consequences of market power exercised in a downstream sector.

The use of complementary inputs is a key characteristic of the production process in many food related industries. Downstream firms frequently purchase inputs and services from different markets to produce final products. In effect, this creates complementarities between primary agricultural inputs and other inputs and services pertaining to packaging, marketing, and distribution. The implication of complementary relationships is that in imperfectly competitive markets, the performance of firms in complementary sectors would be interdependent, even though they do not engage in bilateral interactions. That is, firms' actions in one sector would affect the profitability of firms in the complementary sector.

A good example of this situation occurs within the current North American grain handling and transportation industry (or GHTS), which is a vast agricultural supply chain possessing a concentrated complementary input sector (i.e., rail transportation) operating in a separate market. In this industry, country elevators (grain handlers) need to purchase grain as well as manage rail transportation services for each ton of grain supplied to a terminal port elevator. Due to the complementarities in the supply of grain to these terminal elevators, market power in the rail sector may lead to important consequences for the economic performance of the grain handling industry as well as producer welfare.

The findings of this research will help to shed light on critical and timely policy issues in North American economies. For example, in October 2012 the US Department of Commerce launched an advisory committee that comprises representatives from US industries, academia and government to examine US supply chain competitiveness. One of the stated goals of the advisory committee is to provide input on issues related to national freight infrastructure and policies in order to enhance the competitiveness of US businesses both domestically and globally (USDC, 2012).[iii]

Furthermore, our study will provide insights into a major policy issue in Canadian Agriculture. In August 2012, the Canadian Wheat Board (or CWB) was stripped of its prior functionality as monopoly grain marketer and coordinator of grain logistics and transportation in Western Canada. This change left grain companies to fill the void in both marketing and logistics for Canadian grain, which in turn created much controversy over the potential effects of the new interactions between grain handlers and railways on farmer welfare. Part of the current debate is centered on the question of whether potential market power in an increasingly concentrated grain handling industry will be more harmful to producer welfare as compared to the potential market power of a highly concentrated rail industry.

In fact, the presence of imperfectly competitive complementary sectors in agri-food systems and the implications of this situation regarding the overall performance of these systems have not received very much attention in the literature. As we shall see, existing models have focused mostly on the economic and welfare implications of market power in the downstream sectors of food industries. Ultimately, we offer that the welfare implications of the interplay between potential market power exercised by downstream firms and complementors[iv] are not well understood and deserve further analysis.

Related Literature

Prior literature on competition in agricultural and food industries has generally focused on bilateral relationships between buyers and sellers in a single homogeneous goods market. One strand of this literature measures the degree of competitiveness in a market using the so-called New Empirical Industrial Organization, or NEIO, framework. This approach facilitates the estimation of a conduct parameter (also considered to be the market power index for an industry) under maintained assumptions about the structure of demand and marginal cost. An early example of this type of analysis saw Schroeter (1998) estimate the degree of competitiveness in input and output markets in the US beef packing industry. Mérel (2009) examined conduct in the French comte cheese market, while others have used similar methods to analyze conduct in the US sugar industry (Genesove and Mullin, 1998), the tobacco industry (Raper, Love and Shumway, 2000), and the Canadian beef packing industry (Rude, Harrison and Carlberg, 2011). More recently, Çakır and Balagtas (2012) found statistically significant but economically small cooperative market power in the fluid milk market. All cited works are examples of similarly structured markets in the food and agricultural sector.

A second strand of agricultural economics literature relies on numerical simulation models within the NEIO framework. In this work, functional forms are assigned to the structural demand and supply equations of a market model and explicit forms for the equilibrium outcomes in terms of a parameterized conduct parameter along the unit interval are derived. Then numerical simulation and comparative statics are used to examine the implications of changes in market power for welfare and policy. These models have been applied to a number of different agri-food and other industries. For instance, Alston, Sexton and Zhang (1997) measured the implications of market power on the size and distribution of benefits from agricultural research. Mchardy (2006) measured the welfare effects of a policy that separates a single monopoly into two complementary monopolies. In turn, Sexton and Zhang (2001) studied the distribution of welfare when firms in successive stages of production exert market power, while Sexton et al. (2007) examined how the presence of market power affects the distribution of welfare from trade liberalization. Finally, Saitone, Sexton and Sexton (2008) measured the implications of market power on the effects of agricultural subsidies.

Our research is also founded in the historical economic literature on complementary monopoly. This literature dates back to the work of Cournot (1838), focusing on the analysis of equilibrium outcomes in a market where there are two or more complementary goods, each produced by an independent monopolist and used in the production of a composite product (Cournot 1838, Economides and Salop 1992, Gawer and Henderson 2007, Machlup and Taber 1960, Sonnenschein 1968). Cournot originally considered the merger of two independent monopolists who produced complementary inputs (zinc and copper) into an integrated monopolist that produces the composite product (brass). Cournot showed that the equilibrium price under the merger of the two monopolists is less than the sum of the two input prices when each input is produced by an independent monopolist. The primary explanation for this result is that the independent monopolists do not account for externalities that stem from the interdependencies of their actions, which in turn leads to an undersupply of the composite product.

In the context of agricultural supply chains, Cournot's result implies that market power in a complementary input sector may well have important consequences for the overall performance of the supply chain, as well as on consumer and producer welfare.

Although complementarities in agricultural and food supply chains are common, related prior literature has focused almost exclusively on the analysis of market power in the downstream sector.

In this study, we contribute to the literature on the industrial organization of agricultural and food markets by investigating consequences stemming from the exertion of market power in a complementary input sector. Specifically, we address the importance of welfare consequences associated with market power in a complementary input sector compared to the consequences of market power exerted in a downstream sector. To achieve this, we build a model of a homogenous product market that encompasses both bilateral and complementary relationships. The model is developed around the primary input sector and allows for the exertion of market power by both complementors and downstream firms. We then use comparative statics and numerical simulations to conduct our welfare analysis. With respect to the welfare of primary input suppliers (i.e. farmers), we show that the market power exercised by the supplier of a complementary input generates larger negative effects than the same level of market power exercised by downstream firms.

The remainder of the article is organized as follows. In the next section we build a flexible analytic model of a market setting in which both downstream firms and complementors can potentially exercise market power. Subsequently, to perform the numerical analysis we derive the equilibrium outcomes of the model in explicit form under the assumptions of linear demand and supply, constant long-run marginal costs and fixed proportions technology. Then, we assess comparative statics and generate numerical simulation results. In the sixth section, we briefly discuss our results as they relate to the current situation in the Canadian GHTS. A final section concludes.

An NEIO Model of Complementary Input and Downstream Market Power

To begin, we generalize a stylized model of oligopoly/oligopsony in a homogenous product industry (e.g., see Bresnehan, 1989, for a review) so as to capture both bilateral and complementary relationships. Specifically, we consider a market setting that models the interactions of three independent groups of firms producing a composite commodity. The first group of firms (referred to here as downstream firms) produce a composite commodity using two inputs, while the second group of firms (referred to here as upstream firms) produce the primary input for the downstream firms, while the third group of firms (referred to here as complementors) produce complementary inputs and/or services for the production of the composite commodity.

To help buttress these ideas, we again consider the current North American GHTS. In this industry, the upstream primary input sector comprises numerous competitive grain farmers who sell their product to a concentrated grain handling industry, i.e., grain companies/elevators. In turn, elevators manage services from a highly concentrated railway industry in order to move the grain to their port terminal elevators for export. We assume that the two inputs provided by farmers on one hand, and railways on the other are perfect complements and used in fixed proportions for each ton of grain supplied to a terminal elevator. In addition, railways and farmers face a derived demand for grain, but they are not within the same vertical market channel, so on an operational level they do not interact with each other.[v]

A flexible analytic model of this market setting allows us to analyze the implications of a wide range of competitive outcomes. Once again, we assume that the primary input is produced by a large number of competitive suppliers, whereas downstream firms and complementors can be much more concentrated and could potentially exercise market power. Downstream firms may possess market power in both their output and the primary input markets, while complementors may possess market power in their output market. Let the inverse demand for the composite commodity and the inverse supply for the primary input be given by:

$$p^{d} = D(Q^{d}, Y), \tag{1}$$

$$p^{u_1} = S(Q^{u_1}, Z), \tag{2}$$

where p^{d} and p^{u_1} are the prices received by the downstream and upstream firms, respectively; $Q^{(.)}$ is the industry quantity, while Y and Z are vectors of demand and supply shifters, respectively. Suppose that the complementary input is produced at a constant marginal cost of c^{u_2} and traded at a price p^{u_2}. Assuming fixed proportions, we set $Q = Q^{d} = Q^{u_1} = Q^{u_2}$.[vi] Under the latter assumption about technology, the marginal cost of the composite commodity can be expressed as:

$$C^{d} = p^{u_1} + p^{u_2} + c^{d}, \tag{3}$$

where c^{d} is the constant per unit cost of production.

In the following subsections, we first derive equilibrium outcomes for the general case in which downstream firms may have market power in both their output and the primary input markets, while complementors may have market power in their output market. Then, we derive and compare equilibrium outcomes for three subcases: i) downstream firms may have oligopoly market power, ii) downstream firms may have both oligopoly and oligopsony market power, iii) complementors may have oligopoly market power.[vii]

Case 1: Downstream firms may have both oligopoly and oligopsony power, complementors may have oligopoly power

In this case downstream firms set their perceived marginal revenue, PMR^d, equal to perceived marginal cost, PMC^d. Let us define parameter indexes λ^d and ξ^d that measure downstream firms' oligopoly and oligopsony market power, respectively. Under the Cournot model of competition with symmetric firms these parameter indices take values between zero and one. At the two extremes when $\lambda^d = 0$ or $\lambda^d = 1$, the downstream market is characterized as perfectly competitive or as a monopoly in their output market, respectively.

From (1) and (3) the PMR and PMC equations can be derived as $PMR^d = p^d + \lambda^d D'(Q)\, Q$ and $PMC^d = p^{u_1} + p^{u_2} + c^d + \xi^d S'(Q)Q$. The downstream firms' pricing equation can be obtained as:

$$p^d = p^{u_1} + p^{u_2} + c^d + \xi^d S'(Q)Q - \lambda^d D'(Q)Q. \quad (4)$$

Given that the downstream firms behave according to (4) the inverse derived demand faced by complementors is:

$$p^{u_2} = p^d - p^{u_1} - c^d - \xi^d S'(Q)Q + \lambda^d D'(Q)Q. \quad (5)$$

Equation 5 yields valuable insight into how downstream firms' market power affects complementor pricing behavior. Suppose that the primary demand and the farm supply curves have negative and positive slopes over the relevant range of production, respectively, i.e., $S'(Q) > 0, D'(Q) < 0$. Equation 5 shows that the downstream firms' oligopoly market power rotates down the derived demand facing the complementors, a well-known result from successive oligopoly models of vertical market channels (e.g., Çakır and Balagtas, 2012). In turn, this reduces the elasticity of the derived demand curve and limits complementors potential mark-up, i.e., $\frac{\partial p^{u_2}}{\partial \lambda^d} < 0$. A second result to consider is that downstream firms' oligopsony market power in their primary input market has the same effect as their oligopoly power on the pricing behavior of complementors, i.e., $\frac{\partial p^{u_2}}{\partial \xi^d} < 0$; this occurs even though complementors and upstream firms are not within the same vertical market channel.

Now we define a parameter index λ^{u_2} that measures complementors' oligopoly market power. Similarly, under the Cournot model of competition with symmetric firms, λ^{u_2} takes values between zero and one, with $\lambda^{u_2} = 0$ and $\lambda^{u_2} = 1$ characterizing the two extremes of perfect competition and monopoly, respectively. Again, complementors set their perceived marginal revenue equal to marginal cost, $PMR^{u_2} = c^{u_2}$. From (5) we can derive PMR^{u_2} and obtain the complementors' pricing equation as:

$$p^{u_2} = c^{u_2} - \lambda^{u_2}[(D'(Q)Q - S'(Q)Q - \xi^d(S''(Q)Q^2 + S'(Q)Q) + \lambda^d(D''(Q)Q^2 + D'(Q)Q)]. \quad (6)$$

For the implementation of the numerical simulation model, we need to express the pricing equations in elasticity form. Thus, the downstream firms' pricing equation can be expressed as:

$$p^d \left(1 + \frac{\lambda^d}{\eta_1}\right) = p^{u_1}\left(\frac{\xi^d}{\epsilon}\right) + p^{u_2} + c^d, \tag{7}$$

where $\eta_1 = \left(D'(Q)\frac{Q}{p^d}\right)^{-1}$ and $\epsilon = \left(S'(Q)\frac{Q}{p^{u_1}}\right)^{-1}$ are the demand and supply elasticities, respectively. Under the assumption of linear demand and supply schedules (i.e., $D''(Q) = S''(Q) = 0$) the complementors' pricing equation can be written as:

$$p^{u_2}\left(1 + \frac{\lambda^{u_2}}{\eta_2}\right) = p^{u_1}\left(\frac{(1+\xi^d)\lambda^{u_2}}{\epsilon}\right) + c^{u_2}, \tag{8}$$

where $\eta_2 = \left((1 + \lambda^d)D'(Q)\frac{Q}{p^{u_2}}\right)^{-1}$ is the derived demand elasticity.

Case II: Downstream firms may have oligopoly market power

In this case, complementors are assumed to be price takers in their output market, i.e., $\lambda^{u_2} = 0$, and downstream firms are assumed to be price takers in their primary input market. Here, the pricing equation of downstream firms is derived from Equation (7), by setting $\xi^d = 0$ and $p^{u_2} = c^{u_2}$:

$$p^d\left(1 + \frac{\lambda^d}{\eta_1}\right) = p^{u_1} + c^{u_2} + c^d. \tag{9}$$

Case III: Downstream firms may have both oligopoly and oligopsony market power (oligopsony in the primary input market)

As in Case II, the complementors' pricing equation is simply their marginal cost. The downstream firms' pricing equation is the same as Equation (7) with $p^{u_2} = c^{u_2}$.

Case IV: Complementors may have oligopoly market power

In this case, downstream firms are price takers in both their input and output markets. Their pricing equation is $p^d = p^{u_1} + p^{u_2} + c^d$. The pricing equation of the complementors is derived from Equation (8) by setting $\lambda^d = 0$ and $\xi^d = 0$,

$$p^{u_2}\left(1 + \frac{\lambda^{u_2}}{\eta_3}\right) = p^{u_1}\left(\frac{\lambda^{u_2}}{\epsilon}\right) + c^{u_2}, \quad (10)$$

where $\eta_3 = \left(D'(Q)\frac{Q}{p^{u_2}}\right)^{-1}$ is the derived demand elasticity.

Numerical Simulations using the Model

In this section, we specify simple linear functional forms for the demand and supply equations in (1) and (2) in order to obtain explicit solutions for the equilibrium outcomes of each case and perform numerical simulations accordingly. There are two advantages to using a linear numerical simulation model in this case. First, it provides a basis for comparison against the results of prior studies concerning the implications of market power in downstream sectors for both welfare and policy (e.g., Sexton, 2000; Sexton and Zhang, 2001; Sexton et al., 2007). Second, the linear simulation model of this NEIO framework greatly simplifies the derivation and presentation of analytical results. In their study of the distribution of agricultural research benefits in the presence of imperfect competition, Alston, Sexton and Zhang (1997) compared the results of a similar linear model to results derived under alternative functional form specifications of the demand and supply equations (i.e., quadratic and square root functional forms), illustrating that the alternative models yielded similar results.

Let the demand for the composite commodity and the inverse supply for the primary input be given by:

$$Q \quad = \; a \; - \alpha \, p^d, \tag{1'}$$

$$p^{u_1} \; = \; b + \beta Q, \tag{2'}$$

where $\alpha > 0$ and $\beta > 0$. Under perfect competition $p^{u_2} = \; c^{u_2}$ and $p^{u_1} = p_c^d - \; c^d - c^{u_2} = f$, where the subscript c denotes the perfectly competitive outcome and f is the primary input suppliers' revenue share under perfect competition. Without loss of generality, we use normalizations such that the downstream firms' price and market quantity under perfect competition are set to unity, $p_c^d = \; 1, Q_c = 1$. Then, from the demand and supply equations given in (1') and (2'), the following important relations can be derived: $a = 1 + \alpha$, $b = f - \beta$, $\varepsilon = \frac{p^{u_1}}{\beta Q}$, $\eta = -\frac{\alpha p^d}{Q}$.

For the general case (Case 1) in which downstream firms may have both oligopoly and oligopsony power while complementors may possess oligopoly power, the equilibrium outcomes are obtained by solving the pricing equations in (7) and (8) together with (1') and (2'), yielding:

$$Q_1 = \frac{1+\alpha\beta}{\Gamma_1}\;, \;\; p_1^{u_1} = b + \beta Q_1, \;\; p_1^{u_2} = \left((1+\xi^d)\beta + \frac{1+\lambda^d}{\alpha}\right)\lambda^{u_2} Q_1 + \; c^{u_2}, \;\; p_1^d = \frac{a - Q_1}{\alpha} \tag{11}$$

where $\Gamma_1 = \; (1 \; + \; \lambda^{u_2}) \; [(1 \; + \; \lambda^d) + \alpha\beta(1 + \xi^d)] = (1 \; + \; \lambda^{u_2}) \; [(1 \; + \; \lambda^d) + f\phi_c(1 + \xi^d)]$, and $\phi_c = \frac{\eta_c}{\epsilon_c}$ is the ratio of the absolute value of the elasticity of demand for the composite commodity to the supply elasticity of the primary input, evaluated at the competitive equilibrium.

Here, Γ_1 is the measure of the total distortion to output as compared to the perfectly competitive outcome. The term indicates that market power in each sector of the production process adds to total output distortion, e.g., $\frac{\partial \Gamma_1}{\partial \lambda^{(\cdot)}} > 0$, and also decreases the equilibrium quantity in the market, i.e., , $\frac{\partial Q_1}{\partial \Gamma_1} \frac{\partial \Gamma_1}{\partial \lambda^{(\cdot)}} < 0$. If all markets are competitive, then $\Gamma_1 = 1 + \alpha\beta$ yields the quantity under perfect competition, i.e., $Q_1 = 1$. Also, close inspection of Γ_1 reveals that the complementors' oligopoly power magnifies the distortionary effects of the downstream firms' market power by a factor of $(1 + \lambda^{u_2})$. This implies that the distortion to output due to the downstream firms' market power would be doubled if the complementary sector is a monopoly, i.e., $\lambda^{u_2} = 1$.

For Case 2, in which downstream firms may have oligopoly power, we solve equation (9) together with (1') and (2') under the assumption that complementors are price takers, i.e., $p_2^{u_2} = c^{u_2}$, to obtain:

$$Q_2 = \frac{1+\alpha\beta}{\Gamma_2}, \; p_2^{u_1} = b + \beta Q_2, \; p_2^{u_2} = c^{u_2}, \; p_2^d = \frac{a - Q_2}{\alpha} \tag{12}$$

where $\Gamma_2 = 1 + \lambda^d$.

Similarly, for Case 3, in which downstream firms may have both oligopoly and oligopsony market power, we solve equation (7) together with (1') and (2'), again under the assumption that complementors are price takers, i.e., $p^{u_2} = c^{u_2}$, to obtain:

$$Q_3 = \frac{1+\alpha\beta}{\Gamma_3}, \; p_3^{u_1} = b + \beta Q_3, \; p_2^{u_2} = c^{u_2}, \; p_3^d = \frac{a - Q_3}{\alpha} \tag{13}$$

where $\Gamma_3 = (1 + \lambda^d) + f\phi_c(1 + \xi^d)$.

Finally, for Case 4, in which complementors may have oligopoly market power, we solve equation (10) together with (1') and (2') under the assumption that downstream firms are price takers, i.e., $p^d = p^{u_1} + p^{u_2} + c^d$, to obtain:

$$Q_4 = \frac{1+\alpha\beta}{\Gamma_4}\ ,\ \ p_4^{u_1} = b + \beta Q_4,\ \ p_4^{u_2} = \left(\frac{1+\alpha\beta}{\alpha}\right)\lambda^{u_2} Q_4 + \ c^{u_2},\ \ p_4^d = \frac{a - Q_4}{\alpha} \tag{14}$$

where $\Gamma_4 = 1 + \lambda^{u_2}$.

Let $i \in \{c, 1,2,3,4\}$. Welfare results in each case can obtained in the following way:

$$CS_i = \int_{p_i^d}^{a/\alpha} (a - \alpha) dp = \frac{\left(a - \alpha\, p_i^d\right)^2}{2\alpha}, \qquad \text{Consumer Surplus} \tag{15}$$

$$PS_i = \int_b^{p_i^{u_1}} \frac{p-b}{\beta} dp = \frac{\left(p_i^{u_1} - b\right)^2}{2\beta}, \qquad \text{Producer (Primary Input Supplier) Surplus} \tag{16}$$

$$\Pi_i = \Pi_i^d + \Pi_i^{u_2} = \left(p_i^d - p_i^{u_1} - 1 \ + \ f\right) Q_i. \qquad \text{Total Profit} \tag{17}$$

Lemma 1: Consumer and producer surplus measures are monotonically decreasing functions of the distortion to industry output due to market power, Γ_i, for values of $\Gamma_i \in \left((1 + \alpha\beta), 4(1 + \alpha\beta)\right)$ for $i \in \{1, 2, 3\}$, and for values of $\Gamma_4 \in (1, 2)$.

Proof of Lemma 1: Using $p_i^{u_1} = b + \ \beta Q_i$ and $p_i^d = \frac{a - Q_i}{\alpha}$, rewrite (15) and (16) as: $CS_i = Q_i^2/2\alpha$ and $PS_i = \frac{\beta Q_i^2}{2}$, respectively. By differentiating these terms with respect to Γ_i we obtain $\frac{\partial CS_i}{\partial Q_i}\frac{\partial Q_i}{\partial \Gamma_i} < 0$ and $\frac{\partial PS_i}{\partial Q_i}\frac{\partial Q_i}{\partial \Gamma_i} < 0$ for values of $\Gamma_i \in \left((1 + \alpha\beta), 4(1 + \alpha\beta)\right)$ for $i \in \{1, 2, 3\}$, and for values of $\Gamma_4 \in (1, 2)$. ■

Proposition 1: Starting from the same degree of market power, an increase in complementors' oligopoly market power generates more welfare losses to consumers and producers than the welfare losses generated by an equivalent increase in downstream firms' oligopoly or oligopsony market power.

Proof of Proposition 1: From equation (11), differentiating Γ_1 with respect to the conduct parameters gives: $\frac{\partial \Gamma_1}{\partial \lambda^d} = (1 + \lambda^{u_2})$, $\frac{\partial \Gamma_1}{\partial \xi^d} = \alpha\beta(1 + \lambda^{u_2})$ and $\frac{\partial \Gamma_1}{\partial \lambda^{u_2}} = 1 + \lambda^d + \alpha\beta(1 + \xi^d)$. Setting $\lambda^{u_2} = \lambda^d = \xi^d \neq 0$ and rearranging gives:

$$\frac{\partial \Gamma_1}{\partial \lambda^{u_2}} = (1 + \lambda^{u_2})(1 + \alpha\beta) > (1 + \lambda^{u_2}) = \frac{\partial \Gamma_1}{\partial \lambda^d}, \text{ for } \alpha > 0 \text{ and } \beta > 0, \quad (18)$$

$$\frac{\partial \Gamma_1}{\partial \lambda^{u_2}} = (1 + \lambda^{u_2})(1 + \alpha\beta) > \alpha\beta(1 + \lambda^{u_2}) = \frac{\partial \Gamma_1}{\partial \xi^d}, \text{ for } \alpha > 0 \text{ and } \beta > 0. \quad (19)$$

Therefore, by Lemma 1, $\left|\frac{\partial CS_1}{\partial \lambda^{u_2}}\right| > \left|\frac{\partial CS_1}{\partial \lambda^d}\right|$, $\left|\frac{\partial CS_1}{\partial \lambda^{u_2}}\right| > \left|\frac{\partial CS_1}{\partial \xi^d}\right|$, $\left|\frac{\partial PS_1}{\partial \lambda^{u_2}}\right| > \left|\frac{\partial PS_1}{\partial \lambda^d}\right|$, and $\left|\frac{\partial PS_1}{\partial \lambda^{u_2}}\right| > \left|\frac{\partial PS_1}{\partial \xi^d}\right|$. ■

Proposition 2: For the same degree of market power, the welfare implications of complementor oligopoly power for producers and consumers are the same as those attributable to the downstream firms' *combined* oligopoly and oligopsony market power.

Proof of Proposition 2: Set $\lambda^{u_2} = \lambda^d = \xi^d \neq 0$ and rewrite the equilibrium quantity in (13) as: $Q_3 = \frac{1+\alpha\beta}{(1+\lambda^{u_2})+f\phi_c(1+\lambda^{u_2})}$. Using $\alpha\beta = f\phi_c$ and rearranging gives the equilibrium quantity in (14): $Q_3 = \frac{1}{1+\lambda^{u_2}} = Q_4$. Therefore, by Lemma 1, $CS_3 = CS_4$ and $PS_3 = PS_4$. ■

Results: Welfare and Profit Distribution Within the Market

We use numerical simulations of the model to examine the effects of imperfect competition in the downstream and complementary sectors with respect to the determination of total economic welfare in this market, as well as its distribution. Noting our equation 11, equilibrium for the general case can be expressed fully by just five parameters: the conduct parameters, $\lambda^d, \xi^d, \lambda^{u_2}$; the market elasticity ratio under perfect competition, ϕ_c; and the primary input share of revenue under perfect competition, f. To focus on the effects of varying the conduct parameters on the equilibrium outcomes, we set parameter values of $f = 0.5$ and $\phi_c = 1$.[viii] These base values imply that under perfect competition, producers receive one-third and consumers receive two-thirds of the total surplus, while downstream firms and complementors make zero economic profit.

With this in mind, we use numerical simulations to produce Figure 1. Overall, the figure shows the percentage loss in producer surplus resulting from the existence of both complementor and downstream firms' market power. Specifically, the upper panel indicates that even a small degree of complementor oligopoly power can have large effects on producer surplus in the primary input market, and that these effects are larger than the effects of downstream firms' oligopoly power. For example, when $\lambda^{u_2} = 0.1$, the loss to producer surplus compared to the base case is approximately 17%, while this effect is 5 percentage points higher than the effect of downstream oligopoly power when $\lambda^d = 0.1$. Similarly, if the complementary market is a duopoly, i.e., $\lambda^{u_2} = 0.5$, the associated loss in producer surplus is approximately 56% compared to the base, whereas it is only about 44% in the case of downstream duopoly when $\lambda^d = 0.5$.

The middle and lower panels in Figure 1 show the combined effects of market power in complementary and downstream sectors on producer surplus. The simulation also confirms that complementor market power magnifies the effects of downstream firms' market power. For example, for values of downstream oligopoly power between 0.1 and 0.5, the loss to producer surplus compared to the base (i.e., perfect competition in all sectors) ranges between 13% and 44%. However, if instead there exists a duopoly structure in the complementary market, then the loss to producer surplus ranges between 61% and 75%. Similarly, note that the loss to producer surplus from the downstream firms combined oligopoly and oligopsony market power is about 17% percent when $\lambda^d = 0.1$ and $\xi^d = 0.1$, whereas a potential duopoly in the complementary market increases this loss to 63%.

Figure 2 summarizes the simulated effects of market power in the downstream and complementary sectors with respect to the distribution of welfare. The top two panels present the distribution of welfare under downstream firms and complementor oligopoly, respectively. Similar to the previous results, comparing these two panels shows that at equal degrees of market power: i) complementor oligopoly generates more losses to consumer and producer surplus than downstream firms' oligopoly power, and ii) complementors make greater profits than downstream firms.

The third panel presents the case in which downstream firms may have both oligopoly and oligopsony power. In fact, the implications of this case for producer and consumer surplus are the same as in the case of complementor oligopoly. Finally, the fourth panel shows the welfare implications of the general case, in which downstream firms have both oligopoly and oligopsony power, while complementors have oligopoly power. As expected, losses to consumer and producer surplus in this case are the highest compared to other cases under the same level of market power.

One finding of interest, presented in fourth panel of Figure 3, is that complementors obtain more profits than downstream firms at each level of market power. For example, suppose the complementary sector is characterized as a duopoly with $\lambda^{u_2} = 0.5$, while the downstream sector is characterized as both a duopoly ($\lambda^{d} = 0.5$) and duopsony ($\xi^{d} = 0.5$). In this instance, even though it may appear that downstream firms must surely possess more market power, in fact they only secure about 29% of the total economic surplus. That total stands in contrast to the complementors, whose share of total economic surplus in the latter case falls to approximately 43%.

Distribution of Benefits from a Policy that Regulates the Complementary Sector

Next we analyze the impact of a policy that regulates an imperfectly competitive complementary sector to enhance competition. In particular, we investigate how the benefits from such regulation would accrue to the other participants in the market. Suppose that before regulation the complementary market is a duopoly and that the regulation achieves a perfectly competitive outcome in this market, i.e., $p^{u_2} = c^{u_2}$. Also, suppose that the downstream firms may have both oligopoly and oligopsony market power.

Figure 3 presents the distribution of benefits both before and after regulation. Note that the distribution of benefits after regulation corresponds to the results of the scenario presented in the third panel of Figure 2, and we reproduce the panel in Figure 3 for ease of comparison. The simulation results show that a concentrated downstream sector may capture the largest portion of benefits from a competition policy that regulates the complementary sector.

As an example, on one hand, if the downstream sector were perfectly competitive, we find that before regulation the complementors, consumers and producers would receive 50, 33.3, and 16.7 percent of the total surplus, respectively. Regulation would raise the shares of consumer and producer surplus to 66.7, and 33.3 percent. On the other hand, if the downstream sector were a duopoly and duopsony, then the complementors, downstream firms, consumers and producers would receive approximately 43, 28.5, 19, and 9.5 percent of the total surplus, respectively, before regulation. After regulation, the share for the downstream sector would increase to 50 percent, whereas the consumer and producer surplus shares would increase to 33.3 percent and 16.7 percent, respectively.

Discussion: Implications of results for welfare and policy in the context of the current issues in the Canadian GHTS

By assessing a model of a homogenous product market that encompasses both complementary and bilateral relationships in an NEIO framework, we uncovered some interesting results. Foremost are the strong welfare consequences of market power in the complementary input market. While market power in the downstream market is important, the welfare effects of market power exerted by the supplier of a complementary input are stronger than the equivalent degree of market power exerted by the downstream (either through oligopoly or oligopsony).

The development of this model was at least partially motivated by a critical and timely policy issue in North American agriculture. In Canada, as of August 2012 the CWB was stripped of its prior functionality as monopoly grain marketer and coordinator of grain logistics and transportation across the Prairies. This drastic policy change left grain companies to fill the void in both marketing and logistics with respect to Canadian grain. This new industrial situation in Canadian grain handling is well characterized by the set of multilateral market relationships that we examine in this paper.

Two crop years after the change in the status of the CWB (i.e., as of the time of this writing in mid 2014), there is still considerable discontent among farmers over significant delivery delays within the grain handling and transportation system. The delays are coupled with a continued backlog in Canada that is at least partially due to a bumper grain crop carrying over from the previous year. Many farmers are now complaining publicly about the behavior of both the grain companies and the railways regarding the magnitude of lost income attributable to the backlog (Globe and Mail, 2014). In response, by June 2014 the Canadian government imposed strict hopper car movement quotas to help remedy the situation.

The Canadian railways have historically borne most of the criticism for service delays or disruptions in the grain handling and transportation system. While the grain companies are still relative newcomers to the marketing and logistics process for these export grains, they also bear some of the blame in the court of public opinion in Canada over the persistence of the backlog. Authorities offered a variety of reasons to explain the persistence of the backlog, including the bumper grain crop carrying from the previous year, extreme winter weather conditions and increased demand for transport from the mining sector. Our study shows that the potential market power exerted by the grain companies and/or railways could be another important reason for the persistence of the backlog.

Consider that in comparison to historical perceptions about the exertion of market power in the Canadian GHTS, we confirm that while market power exertion by grain companies can lead to market distortions and welfare changes, ultimately it is still the railways who hold “most of the cards” with respect to welfare distribution across the sector. Moreover, in spite of some significant merger activity over the past 10 years in Canadian grain handling, the current grain handling sector remains markedly less concentrated (by any objective measure) than the complementary rail transportation sector.

No matter what future policies emerge to solve the problems with the current Canadian grain handling system, not surprisingly we also find that the biggest loser in this market will be farmers. Interpreting the model, it appears that the primary means to ensure farmers are not unduly harmed in the market arises if both the complementary input (rail) and the downstream output (grain handling) markets are relatively competitive. Significant changes have already occurred in the Canadian GHTS. Because of this farmers need to stay mindful that, to the extent that grain handlers and railways exert market power, regulatory changes in the rail sector will provide them a greater welfare benefit compared to policies supporting competition in the grain-handling sector. Ultimately the model shows us that under the same degree of market power, market power exerted in grain handling does not penalize farmers as much as the exertion of market power in grain transportation.

However, our results also show that if there is market power being exerted in the grain-handling sector, most of the benefits from a policy that enhances competitiveness in the rail sector (for an example of such a policy, see Nolan and Skotheim, 2008) could potentially accrue to the grain-handling sector rather than to producers. Clearly, an effective industrial policy targeted to increase both overall sector performance as well as producer welfare will need to explicitly account for the interplay between relative market power in both the grain handling and railway sectors.

Conclusion

The use of complementary inputs is a key characteristic of the production process in many agricultural industries. A complementary input that is produced in an imperfectly competitive market creates profit interdependencies between complementary input suppliers. In other words, market power in a complementary input sector may have important consequences for the overall performance of the food supply chain, as well as for consumer and producer welfare. However, prior related literature has almost exclusively focused on analysis of market power in downstream sectors. In this article we investigate how welfare stemming from market power in a complementary input sector compares to welfare stemming from market power in a downstream sector. Then, we discuss the implications of our results for policy in the context of Canadian GHTS.

Our research generalizes a stylized NEIO model of oligopoly/oligopsony in a homogenous product industry so as to capture both bilateral and complementary relationships. In the model, we consider a market setting that incorporates the interactions of three independent groups of firms: downstream firms producing a composite commodity, upstream firms producing a primary input and complementors producing a complementary input or service for the production of the composite commodity. The model focuses on the primary input sector, which consists of numerous suppliers, and allows for exertion of market power in the concentrated complementary input and downstream sectors. We model an imperfectly competitive sector under assumptions of Cournot competition with symmetric firms, and derive market equilibrium outcomes under four different competition scenarios. Subsequently, we use comparative statics and numerical simulations to conduct detailed welfare and policy analysis.

We find that the oligopoly power exercised by complementors generates greater welfare losses to consumers and producers than welfare losses stemming from downstream firms' equivalent degree of oligopoly or oligopsony market power. In fact, for the same degree of market power, we find that the welfare consequences from complementors' oligopoly power are the same as those due to the downstream firms' *combined* oligopoly and oligopsony market power. We also evaluated the welfare implications of a policy that regulates the concentrated complementary sector in order to achieve a perfectly competitive outcome in this sector. In this situation, our results show that if the downstream sector is imperfectly competitive, more of the benefits from regulation could potentially accrue to the downstream firms than to producers.

Overall, while basic in structure, our model yields important insights into the supply chain competitiveness and participants' welfare. Our model also contributes to a growing literature examining linkages within a set of vertically related industries along with the welfare consequences associated with the exertion of market power among various players in these markets. One of the important implications of the results for policy is that an effective policy targeted to enhance supply chain competitiveness will need to explicitly account for the interplay between relative market powers of all the participants in the supply chain.

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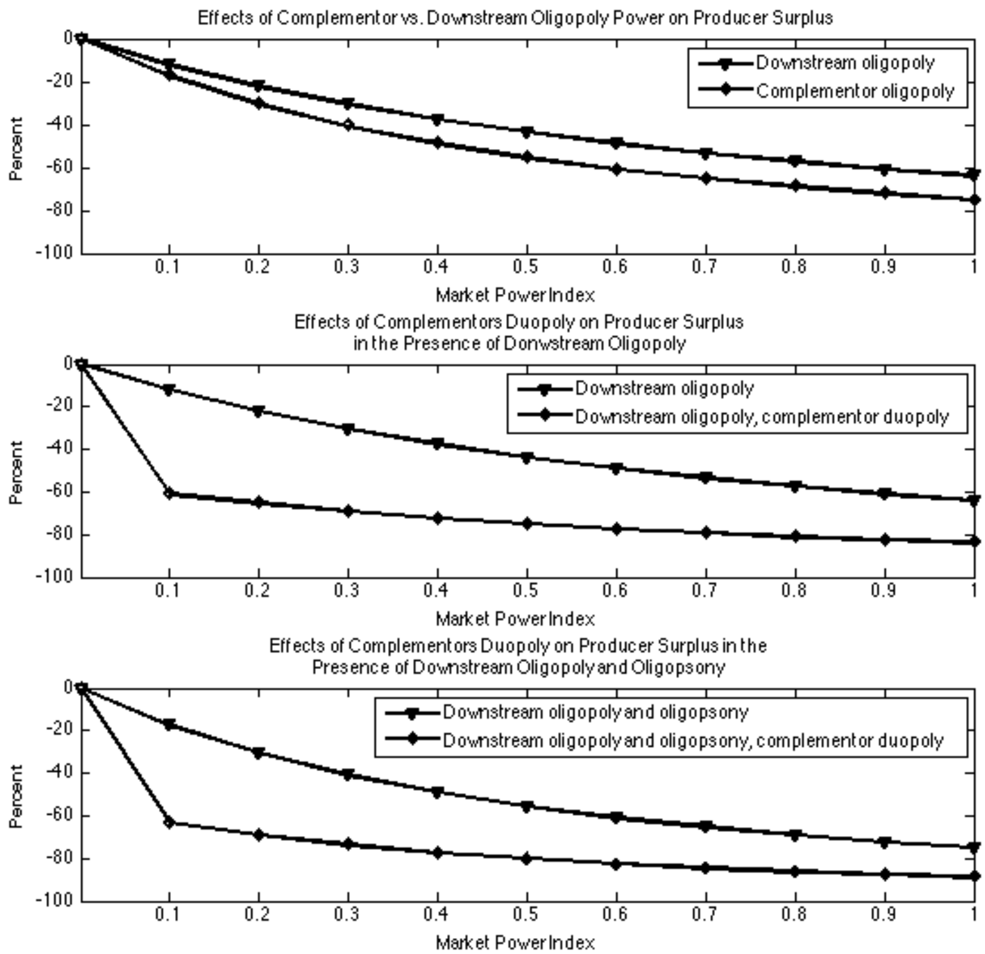

Figure 1: Effects of market power in the complementary input sector on producer surplus

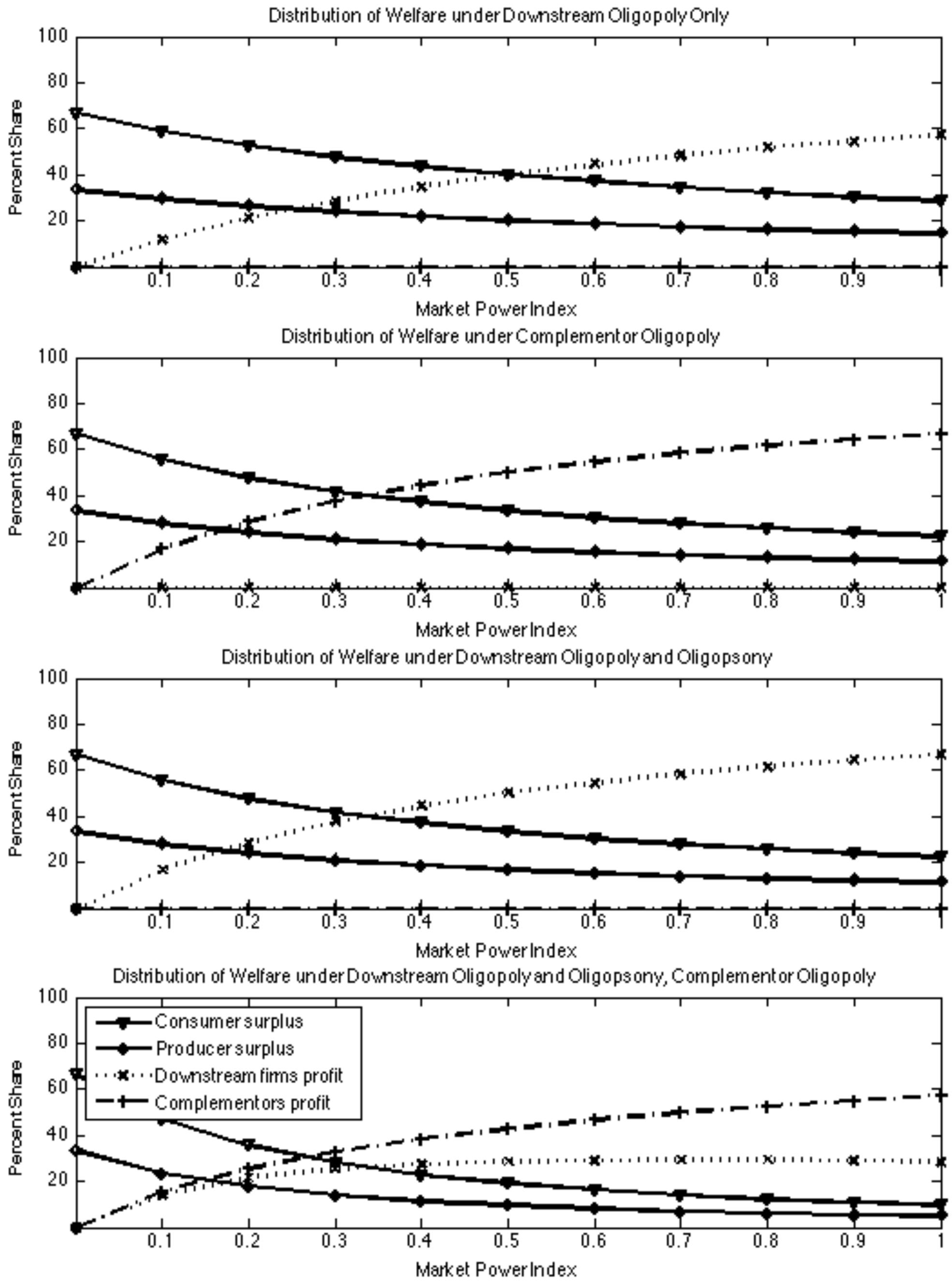

Figure 2: Effects of market power in the downstream and complementary sectors on the distribution of welfare

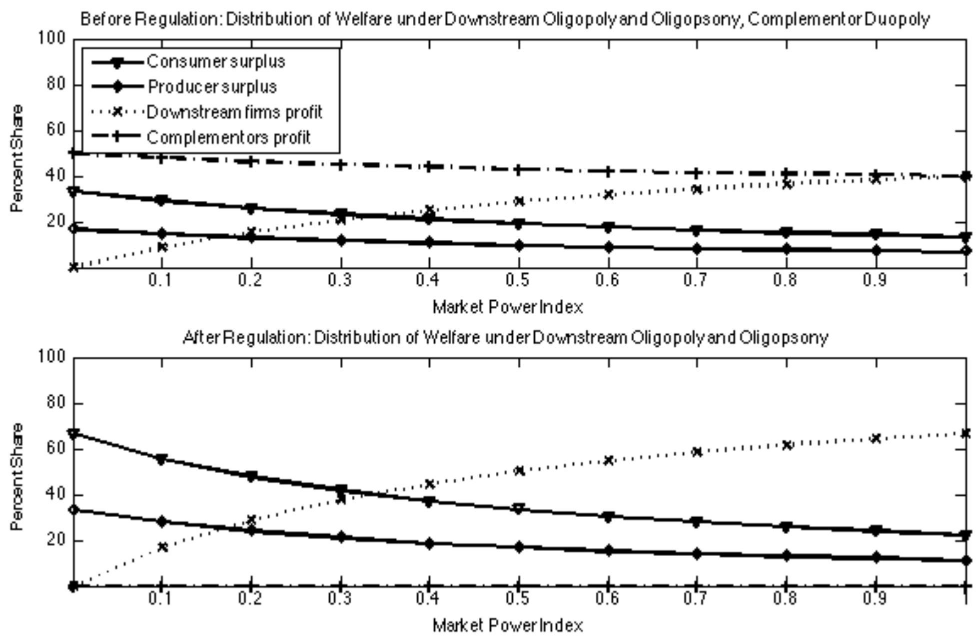

Figure 3: Distribution of benefits from regulating a duopoly complementary sector in the presence of downstream market power

[i] Firms in supply chains usually have two-dimensional interdependencies. In one dimension, firms engage in bilateral interactions with other firms, where upstream firms sell a product to the downstream firms. In the other dimension, firms produce complementary goods or services.

[ii] European Central Bank "Structural Features of Distributive Trades and Their Impact on Prices in the Euro Area", Structural Issues Report, September 2011.

[iii] Source URL (retrieved on *07/12/2014*): http://www.commerce.gov/news/press-releases/2012/10/12/us-department-commerce-announces-launch-advisory-committee-supply-cha

[iv] Following Brandenburger and Nalebuff (2011), we use the term "complementor" as a short hand for the suppliers of complementary inputs and services.

[v] Rail rates for grain are a function of several factors, including shipping distance from port destination and the number of cars to be moved from a specific location (Bonsor, 1984). In Canada, there is still residual regulation in the industry in the form of a mandated cap on railway revenue attributable to grain movement (Canadian Transportation Agency). At present, while grain companies represent farmers in negotiating grain logistics, ultimately rail freight rates are paid by farmers through the grain companies (Quorum, 2002).

[vi] Referring to the situation in the current GHTS, this assumption implies that the quantities of grain that are produced, shipped by rail and demanded at the port are equal.

[vii] The groups of firms that are not mentioned in the title of a case are assumed to be perfectly competitive.

[viii] In fact, the numerical simulation results are qualitatively the same under alternative values of these parameters, including $f = 0.25$ or $f = 0.75$, and $\phi_c = 0.5$ or $\phi_c = 2$.