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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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We explore how market power in a complementary input sector compares to that in a downstream sector for producer and consumer welfare. We develop a model of a homogeneous product market encompassing bilateral and complementary relationships. Our main finding is that market power exercised by the supplier of a complementary input generates greater negative welfare effects than the same level of market power exercised by downstream firms. We provide a discussion of the implications of the results for policy in the context of current problems in the Canadian grain-handling and transportation system.

Key words: complementary sectors, grain handling, market power, supply chain competitiveness, transportation

Introduction

Many food industries in developed countries have characteristically high market concentration, which has been observed in both downstream and complementary sectors of vertical food chains.[1] For example, in 2007, the average four-firm concentration ratio (CR4) for U.S. 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 European Union exceeds 50% (European Central Bank, 2011). Similarly, the 2010 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 agri-food industry trends worldwide raise concerns about whether downstream firms 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 to our knowledge, the implications of potential market power in complementary input sectors have not been previously explored. We fill this void by investigating the economic and welfare consequences of the exertion of market power in a complementary input sector as compared to the economic and welfare consequences of market power exercised in a downstream sector.

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

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, effectively creating complementarities between primary agricultural inputs and other inputs and services pertaining to packaging, marketing, and distribution. In imperfectly competitive markets, the performance of firms in complementary sectors would be interdependent, even though they do not engage in bilateral interactions. Firms' actions in one sector would affect the profitability of firms in the complementary sector.

The North American grain-handling and transportation system (GHTS) is a vast agricultural supply chain possessing a concentrated complementary input sector (i.e., rail transportation) that operates 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.

Concentration in complementary input sectors such as freight transportation and food packaging has important implications for public policy in North American economies. In October 2012 the U.S. Department of Commerce launched an advisory committee made up of industry, academic, and government representatives to examine U.S. 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 U.S. businesses both domestically and globally (U.S. Department of Commerce, 2012). For example, efficient freight transportation is particularly important to the competitiveness of the U.S. grain and oilseeds supply chain, as approximately 30% of all grain and oilseeds in the U.S. is transported by rail (Sparger, 2013). Some of the states in the Upper Midwest are highly dependent on rail, by which more than 80% of all grain and oilseeds are shipped (U.S. Department of Agriculture Office of the Chief Economist and the Agricultural Marketing Service, 2015). However, the U.S. rail industry is also highly concentrated; seven Class 1 railroads currently account for nearly 95% of all railroad revenues. Furthermore, not all railroads provide service in all regions. For example, only two Class 1 railroads serve the western United States (U.S. Department of Agriculture Office of the Chief Economist and the Agricultural Marketing Service, 2015).

In August 2012 the Canadian Wheat Board was stripped of its function 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 controversy over the potential effects of new interactions between grain handlers and railways on farmer welfare. Part of the current debate in Canada centers on whether potential market power in an increasingly concentrated grain-handling industry will be more harmful to producer welfare than the potential market power of a highly concentrated rail industry.

The food-packaging industry in the United States—which produces food cans, beverage cans, and glass containers—is also highly concentrated: the top three manufacturers of glass containers control more than 80% of glass containers sold to U.S. brewers and distillers. In 2014 the Federal Trade Commission argued that a proposed merger between the second- and the third-largest glass manufacturers would harm competition in the market for bottles sold to brewers and distillers but subsequently approved the merger, provided that the acquiring firm would divest six of its own glass plants (Federal Trade Commission, 2014).

Concentration in complementary services may also exist in specific food product categories, local and regional food systems, and smallholder-based value chains in developing countries. However, the presence of imperfectly competitive complementary sectors in agri-food systems and the implications for the overall performance of these systems have not received much attention in the literature. Existing models have focused mostly on the economic and welfare implications of market power in the downstream sectors of food industries. The welfare implications stemming from the

interplay between potential market power exercised by downstream firms and complementors are not well understood and deserve further analysis.[2]

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 New Empirical Industrial Organization (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 (1988) estimate the degree of competitiveness in input and output markets in the U.S. beef packing industry. In the European Union, Mérel (2009) examined conduct in the French comté cheese market, while others have used similar methods to analyze conduct in the U.S. 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 economically small but statistically significant cooperative market power in the fluid milk market. All of these cited works are examples of similarly structured markets in the food and agricultural sector.

A second strand of literature relies on numerical simulation models within the NEIO framework. This work assigns functional forms to the structural demand and supply equations of a market model and derives explicit forms for the equilibrium outcomes in terms of a parameterized conduct parameter along the unit interval. Numerical simulation and comparative statics are then 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. 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 for agricultural subsidies.

Our research is also founded on the historical economic literature on complementary monopoly, which dates back to the work of Cournot (1838), who analyzed equilibrium outcomes in a market in which 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 that produced complementary inputs (zinc and copper) into an integrated monopolist that produced 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 an independent monopolist produces each input. 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 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, prior literature has focused almost exclusively on the analysis of market power in a vertical market chain, accounting only for bilateral relationships

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

between buyers and sellers but not for complementary relationships (e.g., Schroeter, 1988; Çakır and Balagtas, 2012; Sexton, 2000; Sexton and Zhang, 2001; Sexton et al., 2007).

This study contributes to the literature on the industrial organization of agricultural and food markets by investigating the consequences of market power exertion in a complementary input sector. Specifically, we address the welfare consequences associated with market power in a complementary input sector compared to a downstream sector. To achieve this, we build a model of a homogeneous product market encompassing 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 find 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 intuition for this result comes from the differences between the information available to downstream firms and complementors. In effect, downstream firms can exert oligopoly power by using their knowledge of demand for the composite commodity and/or oligopsony power by using their knowledge of supply for the primary input. But complementors can exert oligopoly power by using their knowledge of derived demand, which comprises information on both demand for the composite commodity and supply for the primary input.

The Model

We expand a stylized model of oligopoly/oligopsony in a homogeneous product industry (e.g., Bresnahan, 1989; Sexton, 2000) 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 (downstream firms) produces a composite commodity using two inputs, while the second group of firms (upstream firms) produces the primary input for the downstream firms, and the third group of firms (complementors) produces complementary inputs and/or services for the production of the composite commodity.

We again refer to the situation in the North American GHTS, in which the primary upstream input sector comprises numerous competing grain farmers who sell their product to a concentrated grain-handling industry (i.e., grain companies/elevators). Elevators manage services from a highly concentrated rail industry in order to move grain to their port terminal elevators for export. We assume that the two inputs provided by farmers and railways 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 one other.[3]

A flexible analytic model of this market setting allows us to analyze the implications of a wide range of competitive outcomes. 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

[3] 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). While grain companies represent farmers in negotiating grain logistics, rail freight rates are ultimately paid by farmers through the grain companies (Quorum Corporation, 2002).

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; $Q^{(\cdot)}$ is the industry quantity; and Y and Z are vectors of demand and supply shifters. Suppose that the complementary input is produced at a constant marginal cost of c^{u_2} and traded at price p^{u_2}. Assuming fixed proportions technology, we set $Q = Q^d = Q^{u_1} = Q^{u_2}$.[4] 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 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.[5]

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. We define parameter indexes λ^d and ξ^d to measure downstream firms' oligopoly and oligopsony market power, respectively. These are also known as conjectural elasticities, λ^d and ξ^d, and by assumption take values between 0 and 1. At the two extremes, $\lambda^d = 0$ and $\lambda^d = 1$, the downstream market is characterized as perfectly competitive or as a monopoly in its output market.[6]

From equations (1) and (3), the PMR and PMC equations can be derived as $PMR^d = p^d + \lambda^d D'(Q)Q$ and $PMC^d = p^{u_1} + p^{u_2} + c^d + \xi^d S'(Q)Q$.[7] The downstream firms' pricing equation can be written as[8]

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

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

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

[4] 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.

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

[6] The market power index, λ, corresponds to the conduct of $1/\lambda$ firms under the special case of Cournot equilibirum with symmetric firms. For example, a value of $\lambda^d = 0.1$ ($\xi^d = 0.1$) corresponds to the conduct of a ten-firm symmetric Cournot oligopoly (oligopsony).

[7] An industry with oligopoly (oligopsony) power behaves as though it faces a perceived marginal revenue (perceived marginal cost) curve. The perceived marginal revenue (perceived marginal cost) curve is a linear combination of the marginal revenue (marginal factor cost) curve and the market demand (factor supply) curve, with λ^d (ξ^d) as the weight attached to the marginal revenue (marginal factor cost) curve and $1 - \lambda^d$ ($1 - \xi^d$) as the weight attached to the market demand (factor supply) curve, (Melnick and Shalit, 1985). Formally, $PMR^d = \lambda^d(D'(Q)Q + D(Q)) + (1 - \lambda^d)D(Q) = D(Q) + \lambda^d D'(Q)Q$ and $PMC^d = \xi^d(S'(Q)Q + S(Q)) + (1 - \xi^d)S(Q) + p^{u_2} + c^d = S(Q) + \xi^d S'(Q)Q + p^{u_2} + c^d$.

[8] The representative downstream firm's profit equation can be expressed as $\pi^d = (p^d(Q) - p^{u_1}(Q) - p^{u_2} - c^d)q^d$, where q^d is its output. Maximization of π^d with respect to q^d yields the first-order condition $PMR^d = PMC^d$.

Equation (5) yields valuable insight into how downstream firms' market power affects complementors' pricing behavior. Suppose that the demand and supply curves have negative and positive slopes over the relevant range of production, respectively (i.e., $D'(Q) < 0,\ S'(Q) > 0$). Equation (5) shows that the downstream firms' oligopoly market power rotates down the derived demand facing the complementors, which is 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 markup (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, λ^{u_2} takes values between 0 and 1, with $\lambda^{u_2} = 0$ and $\lambda^{u_2} = 1$ characterizing the two extremes of perfect competition and monopoly. Complementors set their perceived marginal revenue equal to marginal cost, $PMR^{u_2} = c^{u_2}$. From equation (5) we can derive PMR^{u_2} and obtain the complementors' pricing equation as[9]

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

Equations (4) and (6) also provide important insights into the differences in pricing rules between complementors and downstream firms. Downstream firms can exert oligopoly power by using knowledge of demand for the composite commodity and/or oligopsony power by using knowledge of the supply for the primary input. For example, in equation (4), λ^d (ξ^d) shows the extent to which downstream firms can use marginal instead of average revenue (factor cost) in their pricing rule (Melnick and Shalit, 1985). Similarly, complementors can exert oligopoly power by using knowledge of derived demand, and λ^{u_2} shows the extent to which complementors can use their marginal revenue in their pricing rule. The important difference between the two is that complementors' marginal revenue comprises composite and simultaneous information about both demand for the composite commodity and supply for the primary input.

To implement the numerical simulation model, we need to express the pricing equations in elasticity form. Thus, the downstream firms' pricing equation (4) can be expressed as

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

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

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

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 ($\lambda^{u_2} = 0$), and downstream firms are assumed to be price takers in their primary input market. Here, the pricing

[9] The representative complementor's profit function can be expressed as $\pi^{u_2} = (p^{u_2}(Q) - c^{u_2})q^{u_2}$, where q^{u_2} is the output of the representative complementor and $p^{u_2}(Q)$ is the inverse derived demand faced by complementors. Maximization of π^{u_2} with respect to q^{u_2} yields the first-order condition $PMR^{u_2} = c^{u_2}$.

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, complementors' pricing equation is simply their marginal cost. The downstream firms' pricing equation is the same as in 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 $\xi^d = 0$:

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

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

Numerical Simulations Using the Model

We adapt a simple linear simulation model developed by Huang and Sexton (1996) and Alston, Sexton, and Zhang (1997) in order to obtain explicit solutions for the equilibrium outcomes of each case and to perform numerical simulations accordingly. There are two advantages to using the linear 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 the NEIO framework greatly simplifies the derivation and presentation of analytical results. For example, 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.

In this example, let the demand for the composite commodity and the inverse supply for the primary input be given by

$$Q = a - \alpha p^d, \tag{11}$$

$$p^{u_1} = b + \beta Q, \tag{12}$$

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 supplier's 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 equations (11) and (12), the following important relations can also 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 pricing equations (7) and (8) together with equations (11) and (12), yielding

$$(13)\qquad \begin{aligned} Q_1 &= \tfrac{1+\alpha\beta}{\Gamma_1}, \quad p_1^{u_1} = b + \beta Q_1, \\ p_1^{u_2} &= \left((1+\xi^d)\beta + \tfrac{1+\lambda^d}{\alpha}\right)\lambda^{u_2} Q_1 + c^{u_2}, \quad p_1^d = \tfrac{a-Q_1}{\alpha}, \end{aligned}$$

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 $\phi_c = \frac{\eta_c}{\varepsilon_c}$ 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, ($\frac{\partial \Gamma_1}{\partial \lambda^{(\cdot)}} > 0$) and decreases the equilibrium quantity in the market ($\frac{\partial Q_1}{\partial \Gamma_1}\frac{\partial \Gamma_1}{\partial \lambda^{(\cdot)}} < 0$). If all markets are competitive, then $\Gamma_1 = 1 + \alpha\beta$ yields the quantity under perfect competition, $Q_1 = 1$. 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 were a monopoly (i.e., $\lambda^{u_2} = 1$). Furthermore, Γ_1 provides a basis for comparison between the distortionary effects of downstream firms' oligopoly and oligopsony market power. Consistent with the findings of previous studies (e.g., Sexton, 2000), Γ_1 indicates that for equal absolute values of demand and supply elasticities (i.e., $\phi_c = 1$), the distortionary effects of downstream firms' oligopoly market power is larger than the effects of their oligopsony market power (i.e., $\frac{\partial \Gamma_1}{\partial \lambda^d} = 1 + \lambda^{u_2} > f(1+\lambda^{u_2}) = \frac{\partial \Gamma_1}{\partial \xi^d}$).[10] This is the case because primary input suppliers receive only a fraction of the value of the composite commodity.[11]

For case 2, in which downstream firms may have oligopoly power, we solve equation (9) together with equations (11) and (12) under the assumption that complementors are price takers (i.e., $p_2^{u_2} = c^{u_2}$) to obtain

$$(14)\qquad Q_2 = \frac{1+\alpha\beta}{\Gamma_2}, \quad p_2^{u_1} = b + \beta Q_2, \quad p_2^{u_2} = c^{u_2}, \quad p_2^d = \frac{a-Q_2}{\alpha},$$

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 equations (11) and (12), again under the assumption that complementors are price takers (i.e., $p^{u_2} = c^{u_2}$) to obtain

$$(15)\qquad Q_3 = \frac{1+\alpha\beta}{\Gamma_3}, \quad p_3^{u_1} = b + \beta Q_3, \quad p_3^{u_2} = c^{u_2}, \quad p_3^d = \frac{a-Q_3}{\alpha},$$

where $\Gamma_3 = (1+\lambda^d) + f\phi_c(1+\xi^d)$.[12]

Finally, for case 4, in which complementors may have oligopoly market power, we solve equation (10) together with equations (11) and (12) under the assumption that downstream firms are price takers (i.e., $p^d = p^{u_1} + p^{u_2} + c^d$) to obtain

$$(16)\qquad Q_4 = \frac{1+\alpha\beta}{\Gamma_4}, \quad p_4^{u_1} = b + \beta Q_4, \quad p_4^{u_2} = \left(\frac{1+\alpha\beta}{\alpha}\right)\lambda^{u_2} Q_4 + c^{u_2}, \quad p_4^d = \frac{a-Q_4}{\alpha},$$

[10] The distortion from market power is determined by market power parameters combined with the elasticity of demand and the supply elasticity of the primary input. If the supply of the primary input is sufficiently inelastic relative to the elasticity of demand (i.e., $\phi_c > 1$), such that $f\phi_c > 1$, then oligopsony power can generate larger distortions than oligopoly power.

[11] The primary implications of the relationship between the distortion measure and market power indices are the same in cases 2, 3, and 4.

[12] The equilibria of cases 2 and 3 have been presented and discussed in prior literature (i.e., Sexton, 2000; Sexton and Zhang, 2001; Sexton et al., 2007). We reproduce these results here for comparison.

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

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

$$CS_i = \int_{p_i^d}^{a/\alpha} (a - \alpha) dp = \frac{(a - \alpha p_i^d)^2}{2\alpha}, \text{ Consumer Surplus;} \tag{17}$$

$$PS_i = \int_{b}^{p_i^{u_1}} \frac{p - b}{\beta} dp = \frac{(p_i^{u_1} - b)^2}{2\beta}, \text{ Producer (Primary Input Supplier) Surplus;} \tag{18}$$

$$\Pi_i = \Pi_i^d + \Pi_i^{u_2} = (p_i^d - p_i^{u_1} - 1 + f) Q_i, \text{ Total Profit.} \tag{19}$$

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 $\Gamma_1 \in ((1 + \alpha\beta), 4(1 + \alpha\beta))$, $\Gamma_2 \in (1, 2)$, $\Gamma_3 \in ((1 + \alpha\beta), 2(1 + \alpha\beta))$, and $\Gamma_4 \in (1, 2)$.

Proof of Lemma 1: Using $p_i^{u_1} = b + \beta Q_1$ and $p_i^d = \frac{a - Q_i}{\alpha}$, rewrite equations (17) and (18) as $CS_i = \frac{Q_i^2}{2\alpha}$ 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 $\Gamma_1 \in ((1 + \alpha\beta), 4(1 + \alpha\beta))$, $\Gamma_2 \in (1, 2)$, $\Gamma_3 \in ((1 + \alpha\beta), 2(1 + \alpha\beta))$, and $\Gamma_4 \in (1, 2)$. ■

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 (13), 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

$$\frac{\partial \Gamma_1}{\partial \lambda^{u_2}} = (1 + \lambda^{u_2})(1 + \alpha\beta) > (1 + \lambda^{u_2}) = \frac{\partial \Gamma_1}{\partial \lambda^d}, \text{ for } \alpha > 0 \text{ and } \beta > 0, \tag{20}$$

$$\frac{\partial \Gamma_1}{\partial \lambda^{u_2}} = (1 + \lambda^{u_2})(1 + \alpha\beta) > \alpha\beta(1 + \lambda^{u_2}) = \frac{\partial \Gamma_1}{\partial \xi^d}, \text{ for } \alpha > 0 \text{ and } \beta > 0. \tag{21}$$

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

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 equation (15) 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 equation (16): $Q_3 = \frac{1}{1 + \lambda^{u_2}} = Q_4$. Therefore, by Lemma 1, $CS_3 = CS_4$ and $PS_3 = PS_4$. ■

Welfare and Profit Distribution within this Market

Now 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 equation (13), equilibrium for the general case can be expressed fully by just five parameters: conduct parameters, λ^d, ξ^d, λ^{u_2}; 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 equilibrium outcomes, we set parameter values of $f = 0.5$ and $\phi_c = 1$.[13] These base values imply that producers receive

[13] 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 $\phi_c = 2$.

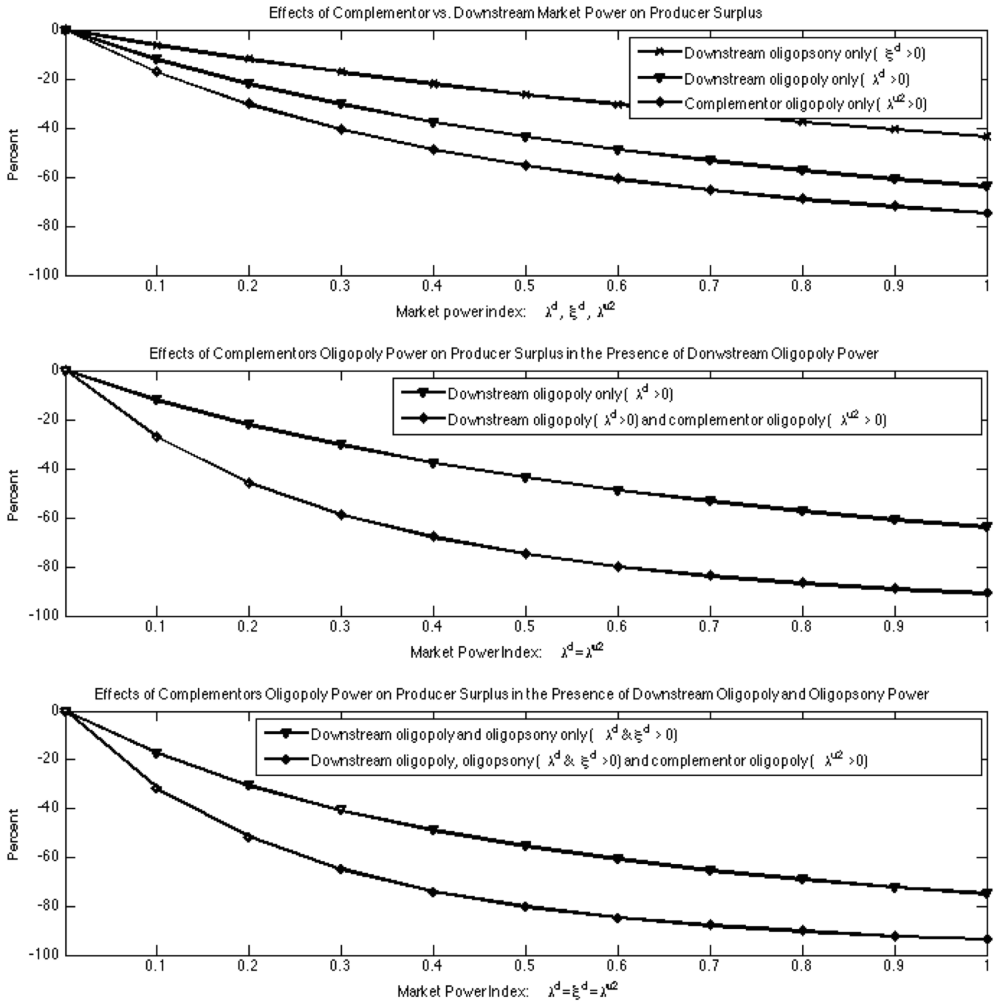

Figure 1. Effects of Market Power on Producer Surplus in the Complementary Input Sector

one-third of the total surplus and consumers receive two-thirds under perfect competition, while downstream firms and complementors make zero economic profit.

Under these assumptions, we use numerical simulations to produce figure 1, which 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 greater than the effects of downstream firms' oligopoly or oligopsony 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 five and eleven percentage points higher than the effects of downstream oligopoly power when $\lambda^d = 0.1$ and oligopsony power $\xi^d = 0.1$, respectively. Similarly, if the complementary market is a duopoly (i.e., $\lambda^{u_2} = 0.5$), then 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 $\lambda^d = 0.5$ and 27% in the case of downstream duopsony when $\xi^d = 0.5$.

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 from 13% to 44%. However, if instead there exists an equal degree of oligopoly power in the complementary market, then the loss to producer surplus ranges from 27% to 75%. Similarly, the loss to producer surplus from the downstream firms combined oligopoly and oligopsony market power is about 17% when $\lambda^d = 0.1$ and $\xi^d = 0.1$, whereas market power in the complementary market when $\lambda^{u_2} = 0.1$ increases this loss to 32%.

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 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 as compared to other cases under the same level of market power.

One finding of interest, presented in fourth panel of figure 2, 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%.

A narrower focus on select values of market power parameters allows delineation of a clearer picture of welfare distribution. Figure 3 illustrates welfare distribution for values of the market power index equal to 0.2 under each of the scenarios. For example, in the case of complementors' oligopoly power only (i.e., $\lambda^d = 0$, $\xi^d = 0$, $\lambda^{u_2} = 0.2$), consumers, producers, and complementors receive approximately 48%, 24%, and 29% of total welfare, respectively. In this case, consumers and producers are worse off compared to the case of the downstream firms' having oligopoly power only (i.e., $\lambda^d = 0.2$, $\xi^d = 0$, $\lambda^{u_2} = 0$), while their share of surplus remains the same compared to the case of downstream firms' having both oligopoly and oligopsony power, (i.e., $\lambda^d = 0.2$, $\xi^d = 0.2$, $\lambda^{u_2} = 0$).

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 market participants. Suppose that before regulation the complementary market is a Cournot duopoly (i.e., $\lambda^{u_2} = 0.5$) 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 4 presents the distribution of benefits both before and after regulation. The distribution of benefits after regulation corresponds to the results of the scenario presented in the third panel of figure 2, so we reproduce the panel in figure 4 for ease of comparison. The simulation results illustrate that a downstream sector possessing market power may capture the largest portion of benefits from a competition policy that regulates the complementary sector.

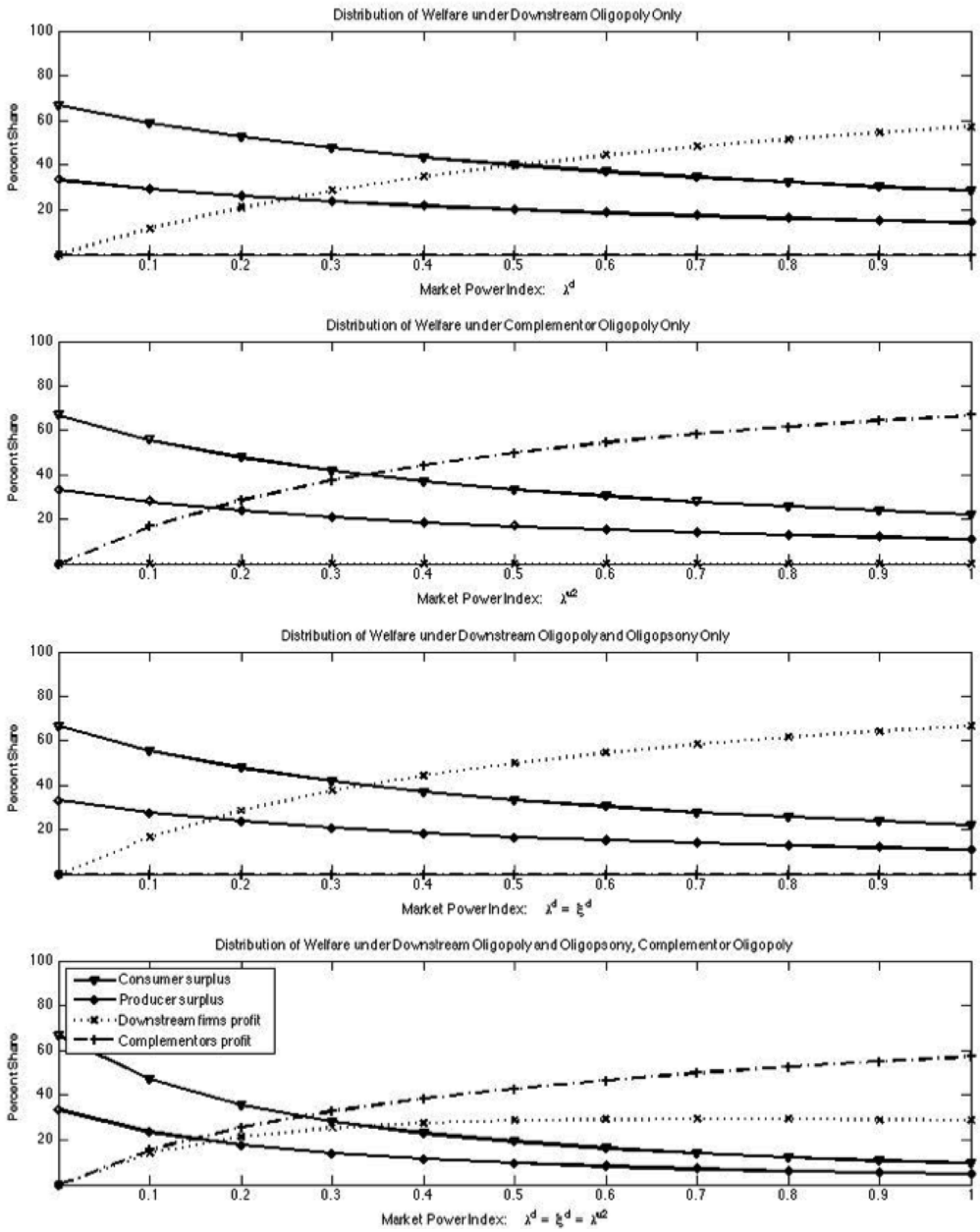

Figure 2. Effects of Market Power in Downstream and Complementary Sectors on Welfare Distribution

As an example, 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% of the total surplus. Regulation would raise the shares of consumer and producer surplus to 66.7% and 33.3%. On the other hand, if the downstream sector exerted Cournot duopoly and duopsony power (i.e., $\lambda^d = 0.5$ and $\xi^d = 0.5$), then the complementors, downstream firms, consumers, and producers would receive approximately 43%, 28.5%, 19%, and 9.5% of the total surplus before

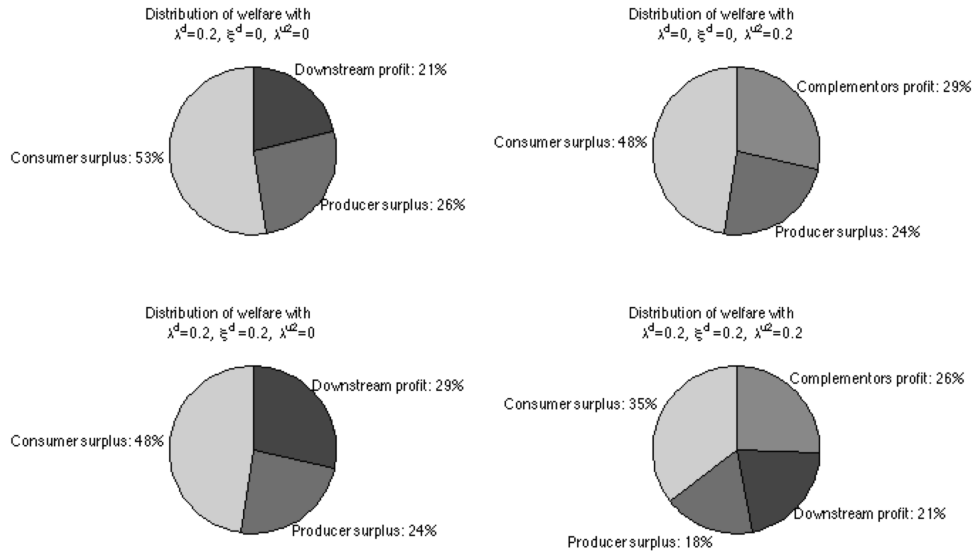

Figure 3. Distribution of Welfare under Select Values of Market Power in Downstream and Complementary Sectors

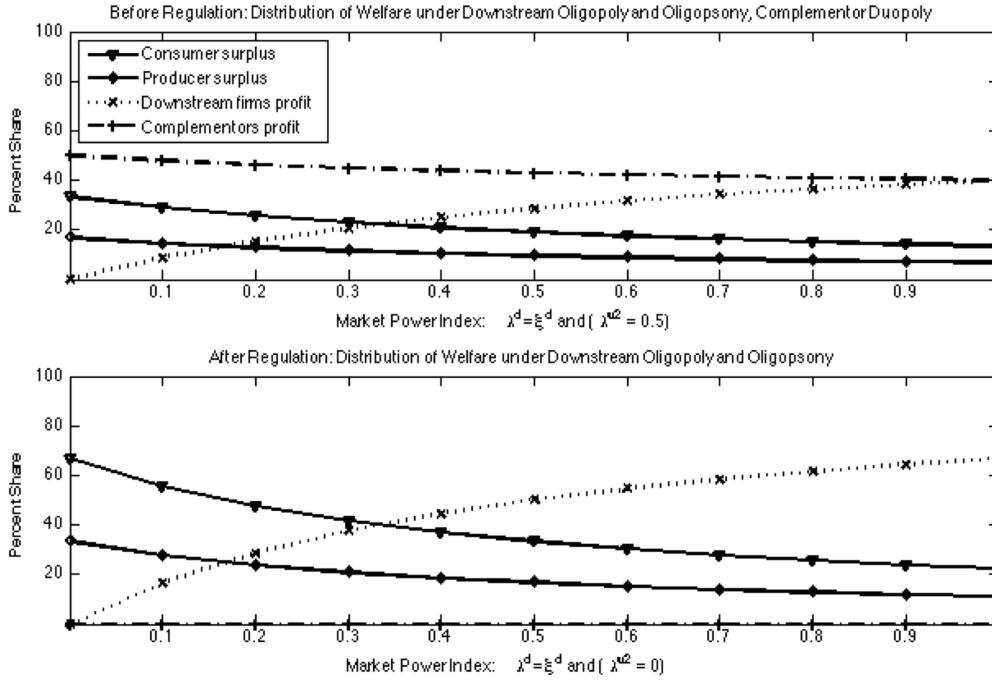

Figure 4. Distribution of Benefits from Regulating a Duopoly Complementary Sector in the Presence of Downstream Market Power

regulation. After regulation, the share for the downstream sector would increase to 50%, while the consumer and producer surplus shares would increase to 33.3% and 16.7%.[14]

Discussion

By developing a model of a homogeneous 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 partially motivated by a critical and timely policy issue in North American agriculture. In August 2012 the Canadian Wheat Board was stripped of its prior function 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 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 Canadian Wheat Board (i.e., at the time of this writing in late 2014), there is still considerable discontent among Canadian farmers over significant delivery delays within the grain handling and transportation system, which are coupled with a continued backlog 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 (Atkins, 2014). In response, in March 2014 the Canadian government imposed strict hopper car movement quotas to help remedy the situation (we note the quotas were removed in March 2015).

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. Industry participants have offered a variety of reasons to explain the persistence of the grain backlog, including the bumper grain crop carrying over from the previous year coupled with extreme winter weather conditions and increased demand for rail transportation from the mining and resource sector. Interpreting the model, we note that an increase in market power exertion by grain companies and/or railways would decrease the amount of grain supplied to the terminal elevators. This implies that an increase in the market power exertion of participants could be another important explanation for the persistence of the grain backlog in Canada.

In comparison to historical perceptions about the exertion of market power in the Canadian grain-handling and transportation sector, 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. 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 system. Farmers will 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.

[14] The results are qualitatively the same if the regulation is not fully effective, such that λ^{u_2} takes any value between $(0, 0.5)$ after regulation.

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 among complementary input suppliers. In other words, market power in a complementary input sector may have important consequences for the overall performance of a food supply chain, as well as for consumer and producer welfare. However, prior related literature has almost exclusively focused analyzing market power in downstream sectors. 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 the Canadian grain-handling and transportation industry.

Our research advances a stylized NEIO model of oligopoly/oligopsony in a homogeneous product industry 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 then 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, compared to the welfare distribution under perfect competition, 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 a complementary sector with market power in order to achieve a perfectly competitive outcome in this sector. In this situation, our results show that if the downstream sector is also imperfectly competitive, more of the benefits from regulation could potentially accrue to the downstream firms than to producers.

Our model yields important insights into supply chain competitiveness and participants' welfare and 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 these results for policy is that an effective policy targeted to enhance supply chain competitiveness will need to explicitly account for the interplay among relative market powers of all the participants in the supply chain.

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