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Baker, Alister Derek; Christensen, Tove

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Innovation in a multiple-stage, multiple-product food marketing chain

Derek Baker and Tove Christensen
E-mail: db@foi.dk, tove@foi.dk

Production and Technology Division, and Consumption, Health and Ethics Division (respectively), Institute for Food and Resource Economics, Faculty of Life Sciences, University of Copenhagen, Rolighedsvej 25, 1958 Frederiksberg C, Copenhagen, Denmark. Senior author’s contact details ph +45-35-28-68-14; e-mail db@foi.dk

Abstract

A model of a 3-stage food marketing chain is presented for the case of two products. Its extension of existing work is its capacity to examine non-competitive input and output markets in two marketing chains at once, and have them related by demand and cost interactions. The simulated impacts of market power in a single chain generally reproduce those delivered by previous authors. The impacts of market power in related chains are found to depend on linkages between chains in terms of interactions in consumer demand. Interactions between products in costs (economies of scope) generate an interesting result in that a possible market failure is identified that may be offset by the exercise of market power. The generation of farm-level innovation is seen to be largely unaffected by market power, but where market power is exercised the benefits are extracted from farmers and consumers. The conditions under which this occurs can also depend on demand interactions. The report identifies commercial and policy implications and future related research topics.

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Preface

This Working Paper presents an algebraic model of a multiple-product, multiple-stage food industry supply system featuring imperfect competition and product interactions. It represents an advance on existing modelling of this type. The model is applied here in tracking the role played by imperfect competition in the transmission of changes in costs and benefits throughout the food marketing chain.

This research is conducted under the auspices of the project¹ “Perspektiver for og Udvikling af den danske fødevarekæde (phase 2)”,² commonly known as “The Food Chain Project”. This project is funded under Innovationsloven and administered by the Directorate for Food, Fisheries and Agribusiness (DFFE) of the Danish Ministry of Food, Agriculture and Fisheries.

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Mogens Lund
Production and Technology Division
Institute of Food and Resource Economics
Copenhagen, May 2008

¹ Further information about the project are available from the author at db@foi.dk.
² “Perspectives and outlook for the Danish food marketing chain”.

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Summary

This Working Paper presents an algebraic model of the food marketing chain. It follows methods developed by various authors based on work by Gardner (1975), as presented in the context of market power by Sexton and Lavoie (2001) and extended to three industry stages by Sexton and Zhang (2001). The current paper provides an advance on that work by introducing multiple products, amongst which the facility exists for interactions in technologies (economies of scope) and demand (substitutability and complementarity).

The model is sensitive to initial specifications of supply and demand parameters, which in the current work are the raw input to specification of elasticities. Other issues of starting values included the output values’ needing to be significantly above unity due to the form of cost functions used. The model’s results show that increasing levels of market power in the food marketing chain reduce output throughout the chain, in a relationship that is convex in market power and more extreme as the number and forms of market power exercised are increased. The same is true for the impact of market power on total welfare, except that the relationship with market power is convex. The model quantifies the extent to which welfare shares are changed due to the exercise of market power. In particular, it allows calculation of surplus accumulated at the stage exercising the market power and surplus lost elsewhere in the chain, in each chain. The expropriation of surplus by one stage from another is closely associated with reductions in price transmission, which is also measured in the model.

Substitution (and complementarity) in consumer demand has a substantial effect on the results generated by the model. The capacity for chain stakeholders to switch between chains in response to (i) price changes in one chain and (ii) the exercise of market power in one or both chains, greatly affects the simulation results. The apparently large influence of demand interactions suggests that firms can benefit from promotions (and other activities) that create or accentuate these interactions. This may generate greater benefits than, for example, efforts to lobby for policy change against the exercise of market power.

The model solution indicates that firms employing technologies featuring economies of scope reduce their profits. The reason is that increased volumes throughout the system raise purchase prices and so raise costs by more than revenues. This effect can be offset by the exercise of market power: restricting volume can also help to control costs. Government action on mergers and acquisition should take account of this: cost
savings due to mergers of large firms may be due to their exercise of market power; and firms that cannot demonstrate cost-related merger justifications may be acting as competitive firms.

A farm-level innovation generates benefits throughout the food marketing chain. That benefit is greater where complementarity in consumer demand occurs with a related product, and less, where the demand interaction features substitutability. Price transmission within the chain, and between chains, is more pronounced under demand complementarity, and less pronounced under substitution specifications. Price transmission, and the transmission of cost reductions through to price reductions, is substantially reduced by the exercise of market power. The exercise of market power in the same chain as that in which the innovation occurs enables firms at one stage of the marketing chain to appropriate the benefits of innovation from other stages.
1. Introduction

1.1. Purpose of study

This report details an economic model of the food marketing chain and presents results from scenarios studied using that model. The aims of the study are to:

1. characterise market power in the food marketing chain in the practical context of multiple products and multiple stages;
2. examine the impact of market power on variables of economic interest, particularly welfare and its allocation amongst food marketing chain stakeholders;
3. characterise the influence of interactions amongst multiple products on the impacts of market power; and
4. examine the case of innovation in the food marketing chain and influence of market conditions on the magnitude and allocation of its benefits.

1.2. The food chain project

This research is conducted under the auspices of the project “Perspektiver for og Udvikling af den danske fødevarekæde (phase 2)”, commonly known as “The Food Chain Project”. This project is funded under Innovationsloven and administered by the Directorate for Food, Fisheries and Agribusiness (DFFE) of the Danish Ministry of Food, Agriculture and Fisheries. The objectives of the project are to:

• measure changes in function, structure and commercial practice in the Danish food industry and compare and contrast these with developments in other countries;
• characterise vertical and horizontal relationships in the Danish food chain and their role in delivering optimal levels of food quality, variety and safety;
• evaluate the efficiency and competitiveness of the Danish food system at each stage of the marketing chain;
• review and evaluate instruments of Danish, EU and foreign public policy in the development of the food marketing chain; and
• communicate research results in a number of media.

Further information about the project are available from the author at db@foi.dk.

“Perspectives and outlook for the Danish food marketing chain”.
The current study advances understanding of the actual and potential impacts of market power in the Danish food marketing chain. As a theoretical piece, its main appeal is to researchers in agricultural marketing and policy. However, the work has practical implications in identifying conditions in which the impacts of market power might be exacerbated or reduced in a multi-product environment. The application to farm-level innovation is of particular interest in the context of changing power balances in the Danish food industry. These aspects of the work have broad appeal to policy makers and industry organisations.

1.3. Background

In the food marketing chain, industrial concentration is occurring simultaneously with advances in technology and changing commercial and consumer behaviour. Trends at both processing and retail stages feature increasing scale (Rogers, 2001) and range of services and products (Kinsey, 2003), as well as new practices in branding (Baker et al., 2005) and purchasing (Young and Hobbs, 2002; OECD, 1999; 2003). This paper examines the influences of market power on welfare throughout the food marketing chain. Its contribution is both methodological and applied. Methodologically, we advance elasticity-based comparative static models to include multiple stages and multiple products. Several applications are examined, particularly farm-level innovation and its impacts throughout a multiple-product system.

In both the United States and Europe, market concentration has accelerated in the past decade in food retailing (USDA, 2002; Dobson, 2003), and in food processing (Rogers, 2001; Baker, 2003; Baker et al., 2008). Increasing concentration in the food industry has been attributed, at least partly, to consolidation based on mergers that capture economies of scale and scope, and imperfectly competitive behaviour. The causes and effects of concentration may well be interacting with the policy process (Wrigley, 2001; Marsden et al., 1997). Of increasing policy interest is the impact of food industry change on each member of the marketing chain and the consumer. Previous authors have identified interaction between costs and the incidence and impacts of imperfect competition. McCorriston et al. (2001) find that the impact of imperfect competition is related to the nature of firms’ technologies, particularly that cost characteristics may either offset or reinforce them in a multiple-product context. Millan (1999) also emphasises the significance of firms’ cost characteristics in models measuring market power and Bhuyen and Lopez (1997) detect the simultaneous presence of economies and scale and imperfect competition in most US food processing sectors. Several empirical studies have concluded that the cost characteristics of firms,
and not their exercise of market power, are the source of observed “excessive” profits in concentrated industries (Morrison Paul, 2001; Hedberg et al., 2000). In this paper, we examine the welfare effects of market power across a range of marketing and technological environments throughout the marketing chain.

A number of simulation models based on Gardner’s (1975) have used multiple-stage equilibrium conditions to model formally the mechanisms by which external shocks are transmitted between stages for a single product. In such approaches, first order profit maximization conditions, in association with equilibrium in vertically-aligned markets, are typically used to generate simulations from assumed values of demand and supply elasticities. A more recent contribution by Sexton and Zhang (2001) focuses on welfare impacts of a range of configurations of market power within a single-product food chain with three stages. Their approach assumes sets of explicit values for conjectural variations in input and output markets, and presents several methodological and practical implications of the relative values of supply and demand elasticities. In the current paper, we extend Sexton and Zhang’s approach to a two-product specification, allowing not only relative values of elasticity to be considered, but also interactions between products in demand (substitution and complementarity) and technology (economies of scope).

Empirical tests for market power in the food industries have centred on estimating conjectural variations in output or input markets at a single stage for a single product. A few authors have measured a single stage’s market power in input and output markets simultaneously (Gobin and Goyumard, 2001), for a single product. Examination of multiple-stage food chains has generally examined the single-product case (Fulton and Tang, 1999). Conversely, tests across several related products (Hyde and Perloff, 1998) and across several food industries (Millan, 1999) have generally addressed a single stage. Addressing multiple products through the whole chain has been attempted using price transmission models (Holloway, 1991; Reed and Clarke, 2000), under the assumption that incomplete price transmission is a likely consequence of market power. In a game theoretic context, Bulow et al. (1985) have identified features of technology and demand in multiple related markets that can dictate firms’ behaviour and the distribution of costs and benefits in each market. We incorporate these empirical findings into our model design, so that model inputs and outputs reflect variables of policy and commercial interest.
1.4. Outline of report

Section 2 introduces a marketing chain comprised of price-taking farmers, processors and retailers with market power in both input and output markets, and price-taking consumers. This section specifies functional forms and the synthesis of optimisation problems at equilibrium. Section 3 describes model solution and presents a set of baseline runs regarding alternative values for elasticities. Section 4 presents and discusses the results of a set of runs addressing each of market power, and cost and demand interactions in the chains. Section 5 is occupied with examination of the impacts of farm level innovation under the various scenarios offered by the model. Section 6 is a discussion of the study and a presentation of conclusions.
2. Model of a multiple-stage, multiple-product food marketing chain

2.1. Component equations

We examine a 3-stage food marketing chain (retail $R$, processing $W$ and farm $F$) with two products ($Y_1$ and $Y_2$). We assume specific forms for the cost functions at all stages and for consumer demand. At the farm stage production of each product features quadratic cost functions with standard characteristics and no interactions between products:

\begin{align*}
    c_1^F(Y_1^F) &= b_1 Y_1^F + \frac{1}{2} \beta_1 (Y_1^F)^2 \\
    c_2^F(Y_2^F) &= b_2 Y_2^F + \frac{1}{2} \beta_2 (Y_2^F)^2
\end{align*}

(1)

where $\beta_1, \beta_2 > 0$. The inverse supply functions $P_i^F(\cdot)$ for price-taking farmers are obtained from (1) and state that output price equals marginal production costs, with:

\begin{align*}
    P_1^F &= b_1 + \beta_1 Y_1^F \\
    P_2^F &= b_2 + \beta_2 Y_2^F
\end{align*}

(2)

In contrast to the farm stage, at each of the retail and the processing stages, firms may produce both products jointly. We specify technologies for $Y_1$ and $Y_2$ that can feature economies of scope. The costs of producing a range of products may be lower (subadditive) or higher (superadditive) than the sum of costs of producing each product alone.

---

5 $\frac{\partial c}{\partial Y} > 0$ and $\frac{\partial^2 c}{\partial Y^2} > 0$.

6 Marginal costs functions are obtained as first derivatives of (1).

7 $y_i$ is the firm’s output and $Y_i$ is industry output, $\sum_i n_i y_i = Y_i = n y_i$ for $n$ identical firms for product $i \in \{1, 2\}$.

8 Economies of scope imply $\frac{\partial^2 c_1}{\partial y_1 \partial y_2} \neq 0$. Costs of producing a range of products may be lower (subadditive) or higher (superadditive) than the sum of costs of producing each product alone.
intensity of economies of scope in the handling, processing, distribution and retailing cost functions applied at stages $R$ and $W$ are represented by $\delta^R, \delta^W \geq 0$ respectively:

$$c_1^R (y_1^R, y_2^R) = (y_1^R)^2(y_2^R)^{-\delta^R}$$

$$c_2^R (y_1^R, y_2^R) = (y_2^R)^2(y_1^R)^{-\delta^R}$$

$$c_1^W (y_1^W, y_2^W) = (y_1^W)^2(y_2^W)^{-\delta^W}$$

$$c_2^W (y_1^W, y_2^W) = (y_2^W)^2(y_1^W)^{-\delta^W}$$

Economies of scope take the form of cost saving arising from improved utilization of equipment, labour and capital, shared costs of quality and safety management practices, and shared distribution activities. Note that in (3) and (4) the trivial case $\delta^R = \delta^W = 0$ reduces the technology to single-product quadratic cost functions. With just two products, $\delta$ must adopt the same magnitude in each of $c_1(\bullet), c_2(\bullet)$ at each stage, but in general $\delta^R \neq \delta^W$.

Linear multi-product aggregate demand functions represent utility-maximising consumers:

$$Y_1^R = a_1 - \alpha_{11} P_1^R - \alpha_{12} P_2^R$$

$$Y_2^R = a_2 - \alpha_{21} P_1^R - \alpha_{22} P_2^R$$

where $\alpha_{12}, \alpha_{21}$ can take signs indicating either substitution or complementarity in consumption, and $a_1, a_2, \alpha_{11}, \alpha_{22} > 0$.

Welfare in the model is measured (following Sexton and Zhang (2001)) as retail and processor profits (see following section) and consumers’ surplus ($CS$, adapted to the 2-product case) and producers’ surplus ($PS$) at the farm level. Consumers’ surplus is defined employing consumer demand (5) as

$$CS = \frac{1}{2} \left[ \frac{a_1}{\alpha_{11}} - \frac{\alpha_{12}}{\alpha_{11}} P_2^R \right] - P_1^R Y_1^R + \frac{1}{2} \left[ \frac{a_2}{\alpha_{22}} - \frac{\alpha_{21}}{\alpha_{22}} P_1^R \right] - P_2^R Y_2^R$$
which geometrically is the sum of the areas under consumer demand curves above $P^R$ for each product. Similarly we employ the linear farm supply functions in (2) to define (farmers’) producers’ surplus geometrically as the sum of areas above supply curves and below $P^F$:

$$PS = \frac{1}{2} \left( P^F_1 - b_1 \right) Y^F_1 + \frac{1}{2} \left( P^F_2 - b_2 \right) Y^F_2$$  \tag{7}

2.2. Profit maximisation

Retail firms face the optimization problem:

$$\max_{y_1^R, y_2^R} \pi^R = P^R_1 (Y^R_1, Y^R_2) y^R_1 + P^R_2 (Y^R_1, Y^R_2) y^R_2 - P^W (Y^W_1, Y^W_2) y^W_1$$

$$- P^W_2 (Y^W_1, Y^W_2) y^W_2 - c^R_1 (y^R_1, y^R_2) - c^R_2 (y^R_1, y^R_2)$$  \tag{8}

where the $P^R (Y^R_1, Y^R_2)$ are consumer demand functions from (5) and the $P^W (Y^W_1, Y^W_2)$ are derived supply functions from stage $W$. Note that we treat the costs of buying the processed product ($P^W_1 (\bullet) y^W_1 + P^W_2 (\bullet) y^W_2$) distinctly from the costs of retail handling and selling ($c^R_1 (\bullet) + c^R_2 (\bullet)$), although the current section is general and the functional forms used in the previous section are employed later. For choice of $y_1$ the first order condition for (8) is:

$$\frac{\partial \pi^R}{\partial y^R_1} = P^R_1 + \frac{\partial P^R_1}{\partial Y^R_1} \frac{\partial Y^R_1}{\partial y^R_1} y^R_1 + \frac{\partial P^R_2}{\partial Y^R_1} \frac{\partial Y^R_2}{\partial y^R_1} y^R_2$$

$$- P^W_1 - \frac{\partial P^W_1}{\partial Y^W_1} \frac{\partial Y^W_1}{\partial y^R_1} y^W_1 - \frac{\partial P^W_2}{\partial Y^W_1} \frac{\partial Y^W_2}{\partial y^R_1} y^W_2 - \frac{\partial c^R_1}{\partial y^R_1} - \frac{\partial c^R_2}{\partial y^R_1} = 0$$  \tag{9}

and an analogue exists for choice of $y_2$. After rearranging, and substitution to introduce elasticities, this can be expressed as an adaptation of Sexton and Lavoie’s (2001) presentation:

$$P^R_1 \left[ 1 + \frac{\Theta^R_1}{\Xi^R_{11}} + \frac{\Theta^R_2}{\Xi^R_{12}} \frac{P^R_2 Y^R_2}{P^R_1 Y^R_1} \right] = P^W_1 \frac{\partial Y^W_1}{\partial y^R_1} \left[ 1 + \frac{\Phi^R_1}{\eta^R_{11}} + \frac{\Phi^R_2}{\eta^R_{12}} \frac{P^W_2 Y^W_2}{P^W_1 Y^W_1} \right] + \frac{\partial c^R_1}{\partial y^R_1} + \frac{\partial c^R_2}{\partial y^R_1}$$  \tag{9}
where \( \Theta^R_1 \equiv \frac{\partial Y^R_1}{\partial y^R_1} \) is the conjectural variation elasticity,\(^9\) a measure of market power, in the retail output market for product \( Y_1 \).\(^{10}\) The analogous measure of market power in product 1’s input markets (i.e. for the processed product) is \( \Phi^R_1 \).

\[
\varepsilon^R_{11} \equiv \frac{\partial Y^R_1}{\partial P^R_1} \frac{P^R_1}{y^R_1} \] is consumers’ own-price elasticity of demand for product 1, \( \varepsilon^R_{11} \leq 0 \).

Processors’ own-price supply elasticity for product 1 is \( \eta^W_{11} \geq 0 \), and cross-price elasticities are denoted \( \varepsilon^R_{12}, \eta^W_{12} \).

The extension to Sexton and Lavoie (2001) that we offer is that of multiple products.

Firstly, the term \( \frac{\Theta^R_1 P^R_2 y^R_2}{\varepsilon^R_{12}} \) on the left hand (revenue) side recognizes that \( P^R_2 \) is affected by change in \( Y^R_1 \). The effect depends not only on the magnitudes of \( \Theta^R_1 \) and \( \varepsilon^R_{12} \), but also on the relative significance of revenues derived from the two products, \( \frac{P^R_2 y^R_2}{P^R_1 y^R_1} \). An analogous input-related term, \( \frac{\Phi^R_1 P^W_2 y^R_2}{\eta^W_{12}} \), appears on the left hand side of (9).

The right hand side term \( \frac{\partial c^R_2}{\partial y^R_1} \) takes account of decline (or rise) in retailers’ costs for \( y_2 \) brought about by marginal increments of \( y_1 \) (i.e. economies of scope). The consequence of cross-price effects is a model solution that is sensitive to interactions in demand and supply between two related food marketing chains, and features sensitivity to interactions between these factors and the exercise of market power.

Similarly, processing firms’ optimisation problem is:

\[
\max \pi^W = P^W_1 (Y^W_1, Y^W_2) y^W_1 + P^W_2 (Y^W_1, Y^W_2) y^W_2 - P^F_1 (Y^F_1) y^F_1 - P^F_2 (Y^F_2) y^F_2 + c^W_1 (y^W_1, y^W_2) - c^W_2 (y^W_1, y^W_2)
\]

---

\(^9\) For a firm, the conjectural variation elasticity is the % change in market volume associated with a unit % change in the firm’s marketed volume. \( \Theta \) and \( \Phi \in [0,1] \), where 0 is associated with perfect competition and 1 with monopoly and monopsony respectively.

\(^{10}\) Assumed identical for all identical firms as maintained by Sexton and Zhang (2001).
which differs from its retail counterpart only in that farm level supply $P_1^F(Y_1^F)$ and $P_2^F(Y_2^F)$ feature no cross-price effects (see (1)). First order conditions yield a processor-stage analogue of (9): \[ P_1^W \left[ 1 + \frac{\Theta_1^W}{\varepsilon_{11}} + \frac{\Theta_1^W}{\varepsilon_{12}} \frac{P_2^W Y_2^W}{P_1^W Y_2^W} \right] = P_1^F \frac{\partial y_1^F}{\partial y_1^W} \left[ 1 + \frac{\Phi_1^W}{\eta_{11}^W} \right] + \frac{\partial c_1^W}{\partial y_1^W} + \frac{\partial c_2^W}{\partial y_1^W} \] (11)

Finally, first order conditions for farmers’ profit maximization are given by

$$P_1^F = \frac{\partial c_1^F}{\partial y_1^F},$$

reflecting perfectly competitive behaviour.

Note that in cases of $\Theta_1^R = \Phi_1^R = 0$ (i.e. no market power in retailers’ output or input markets, then (9) reduces to optimisation under perfect competition with economies of scope:

$$P_1^R = P_1^W + \frac{\partial c_1^R}{\partial y_1^R} + \frac{\partial c_2^R}{\partial y_1^R},$$

which in the absence of economies of scope reduces further to the standard perfect competition case:

$$P_1^R = P_1^W + \frac{\partial c_1^R}{\partial y_1^R},$$

and analogous statements refer to (10) and (11).

Examination of the implications for equilibrium prices, quantities and welfare, of the presence of combinations of market power, consumer demand interactions and technological cost interactions, require the use of specific functional forms and parameter values. In what follows, we investigate combinations of market power in input and output markets at retail and processing stages of the food marketing chain.

\[11\] In (11) the elasticities $\varepsilon_{11}^W$ and $\varepsilon_{12}^W$ refer to the retailers’ (derived) demand for the processors’ output.

\[12\] (a simple mark-up model).
3. Model implementation

3.1. Closure and solution

Without loss of generality we impose the simplifying assumption \( y_1^R = y_1^W = y_1^F \)
(and similarly for product 2) (see Sexton and Zhang, 2001) so that units for the products at each stage such that throughout the marketing chain

\[
\frac{\partial y_1^R}{\partial y_1^W} = \frac{\partial y_1^W}{\partial y_1^F} = 1.
\]

and this derivative vanishes in (9) and (11). This implies that \( Y_1^R = Y_1^W = Y_1^F \) and \( Y_2^R = Y_2^W = Y_2^F \), so that superscripts \( F, W \) and \( R \) are henceforth dropped from \( Y_1 \) and \( Y_2 \). Following Sexton and Zhang (2001) and McCorriston et al. (2001), we interpret the firm level cost functions \( c(y_1, y_2) \) as industry level cost functions \( c(Y_1, Y_2) \) for both products by assuming identical firms at processing and retail stages, respectively. For choice of \( Y_1 \) and \( Y_2 \), six first order conditions (2 at each of 3 stages) and 2 consumer demand equations are combined to provide 8 equations in 8 unknowns \(( P_1^F, P_1^W, P_1^R, P_2^F, P_2^W, P_2^R, Y_1 \) and \( Y_2 \)).

The first step is to formulate inverse consumer demand functions from (5) in order to express prices as quantity-dependent functions in line with statements of first order conditions:

\[
P_1^R = A_1 - A_{11} Y_1 - A_{12} Y_2
\]

\[
P_2^R = A_2 - A_{21} Y_1 - A_{22} Y_2
\]

13 This simplification is equivalent to an assumption of no changes in stocks that differ between stages.
where

\[ A_1 \equiv \frac{a_1 \alpha_{22} - a_2 \alpha_{12}}{\alpha_{11} \alpha_{22} - \alpha_{12} \alpha_{21}} ; A_2 \equiv \frac{a_2 \alpha_{11} - a_1 \alpha_{21}}{\alpha_{11} \alpha_{22} - \alpha_{12} \alpha_{21}} \]

\[ A_{11} \equiv \frac{\alpha_{22}}{\alpha_{11} \alpha_{22} - \alpha_{12} \alpha_{21}} ; A_{22} \equiv \frac{\alpha_{11}}{\alpha_{11} \alpha_{22} - \alpha_{12} \alpha_{21}} \]

\[ A_{12} \equiv \frac{-\alpha_{12}}{\alpha_{11} \alpha_{22} - \alpha_{12} \alpha_{21}} ; A_{21} \equiv \frac{-\alpha_{21}}{\alpha_{11} \alpha_{22} - \alpha_{12} \alpha_{21}} \]

(14)

Next, by using the first order conditions ((9), (11) and (12)), we derive from the specific functional forms ((1)-(4)) two polynomial equations in two unknowns \((Y_1 and Y_2)\), known demand parameters \(a_1, a_2, \alpha_{11}, \alpha_{22}, \alpha_{12} and \alpha_{21}\), supply parameters \(b_1, b_2, \beta_1\) and \(\beta_2\), intensity of economies of scope \(\delta^R\) and \(\delta^W\), and market power parameters \(\Theta_1, \Theta_2, \Phi_1, \Phi_2\) at either or both of stages \(R\) and \(W\). Elasticities (see mathematical appendix) are also able to be expressed as functions of these same variables and parameters.

We limit ourselves to input and output market power exhibited by a single stage (e.g. \(\Theta_1^R, \Phi_1^R \neq 0\)) and sequential market power (e.g. \(\Theta_1^R, \Theta_1^W \neq 0\)): we do not investigate cases of interactions of market power (e.g. \(\Phi_1^R, \Theta_1^W \neq 0\) simultaneously), due to their indeterminate outcomes, usually addressed as a solution to some bargaining procedure (Sexton and Zhang, 2001). The resulting pairs of equations are presented for each of four cases:

---

\[^{14}\text{packaged as } A \text{ parameters in (14)}\]
Case III: Retailer market power in input and output markets

\[ A_2 - b_2 - \left[ A_2 + 2Y_{2w} - 2Y_{2w} + 2Y_{1w} - 2Y_{1w} \right] = 0 \]

Case II: Processor market power in input and output markets

\[ A_2 - b_2 - \left[ A_2 + 2Y_{2w} - 2Y_{2w} + 2Y_{1w} - 2Y_{1w} \right] = 0 \]

\[ (A_2 - b_2) - \left[ (A_2 + 2Y_{2w} - 2Y_{2w} + 2Y_{1w} - 2Y_{1w}) \right] = 0 \]

\( \left[ (A_2 + 2Y_{2w} - 2Y_{2w} + 2Y_{1w} - 2Y_{1w}) \right] = 0 \]

Case I: (Successive) Input market power at both retail and processing stages

\[ A_2 - b_2 - \left[ (A_2 + 2Y_{2w} - 2Y_{2w} + 2Y_{1w} - 2Y_{1w}) \right] = 0 \]

Innovation in a multiple-stage, multiple-product food marketing chain
Case IV: (Successive) output market power at both retail and processing stages

\[
A_1 - b_1 - \left[ (A_1 + A_1 \Theta^R_1)(1+\Theta^W_1) + \beta_1 \right] Y_1 - \left[ A_2 (1+\Theta^W_2 + \Theta^R_2) + A_2 (\Theta^R_1 + \Theta^W_1) \right] Y_2 \\
-2Y_1 Y_2^{-\delta^R} (1+\Theta^W_1 (1-\delta^R)) + \delta^R Y_2^{-\delta^R} [1-\Theta^W_1 (\delta^R + 1) + 2\Theta^W_1] \\
-2Y_1 Y_2^{-\delta^R + \delta^W} Y_2 Y_1^{-(\delta^W + 1)} = 0
\]

(18)

\[
A_2 - b_2 - \left[ (A_2 + A_2 \Theta^R_2)(1+\Theta^W_2) + \beta_2 \right] Y_2 - \left[ A_2 (1+\Theta^W_2 \Theta^R_1) + A_2 (\Theta^R_2 + \Theta^W_2) \right] Y_1 \\
-2Y_2 Y_1^{-\delta^R} (1+\Theta^W_2 (1-\delta^R)) + \delta^R Y_2^{-\delta^R} [1-\Theta^W_2 (\delta^R + 1) + 2\Theta^W_2] \\
-2Y_2 Y_1^{-\delta^R + \delta^W} Y_2^{\delta^W} Y_1^{-(\delta^W + 1)} = 0
\]

Solution of each system (15) to (18) entails finding the roots of each pair of equations, which identifies equilibrium and optimal quantities \(Y_1\) and \(Y_2\).\(^{15}\) Relationships between prices at different stages of the food marketing chain are determined by specifications of cost and market power derived as mark-ups and relationships between elasticities.\(^{16}\)

Second order conditions for profit maximization were tested for all solutions by substitution into a set of Hessian matrices, for which no general functions have yet been derived. A general set of second order conditions is the subject of on-going work. Stability of the model was checked by specifying a wide range of starting values for \(Y_1\) and \(Y_2\) and varying the order of scenarios. Consistency was checked by ensuring that all four model solutions delivered the same equilibrium prices and quantities derived welfare measures when exogenous parameters had been set at the same levels. The special case of perfect competition was used, for each of the four models, in consistency tests. In addition, each pair of equations (15) to (18) can be checked against one other pair for the impact of one of the market power parameters, and this was done to ensure consistency.

\(^{15}\) Microsoft Excel’s “solver” facility was used for the complete set of simulations. Initial results were checked by repeating the process using the “R” freeware.

\(^{16}\) See mathematical appendix.
3.2. Initial values

Mindful of past work demonstrating the sensitivity of multiple-stage models to absolute and relative magnitudes of elasticity at retail and farm stages, seven alternatives were examined. The approach taken here involves specification of supply and demand linear parameters (rather than elasticities), so that elasticity values are (i) derived and (ii) non-constant as adjustment occurs along linear “curves”.

Table 1 presents the elasticity specifications used, listed A-G. All specifications yielded identical results under perfect competition and without product interactions. Section 3.3 reports departures from that result as simulated market conditions are changed in the model. Following previous work, the specification C ($\varepsilon = \eta$) is used from section 4 onwards.

<table>
<thead>
<tr>
<th>Elasticity specification</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relativity</td>
<td>$\varepsilon &lt; \eta$</td>
<td>$\varepsilon &gt; \eta$</td>
<td>$\varepsilon = \eta$</td>
<td>$\varepsilon \to \infty$</td>
<td>$\eta \to \infty$</td>
<td>$\varepsilon \to 0$</td>
<td>$\eta \to 0$</td>
</tr>
<tr>
<td>$a_1$</td>
<td>4</td>
<td>400</td>
<td>20</td>
<td>400</td>
<td>4</td>
<td>4</td>
<td>400</td>
</tr>
<tr>
<td>$a_2$</td>
<td>4</td>
<td>400</td>
<td>20</td>
<td>400</td>
<td>4</td>
<td>4</td>
<td>400</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>0.21</td>
<td>2.5</td>
<td>0.21</td>
<td>0.21</td>
<td>0.21</td>
<td>0.0021</td>
<td>1</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>0.21</td>
<td>2.5</td>
<td>0.21</td>
<td>0.21</td>
<td>0.21</td>
<td>0.0021</td>
<td>1</td>
</tr>
<tr>
<td>$b_1$</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>0.5</td>
<td>5</td>
<td>5</td>
<td>-350</td>
</tr>
<tr>
<td>$b_2$</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>0.5</td>
<td>5</td>
<td>5</td>
<td>-350</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>0.00025</td>
<td>10</td>
<td>1.8</td>
<td>1000</td>
<td>0.025</td>
<td>0.00025</td>
<td>10000</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>0.00025</td>
<td>10</td>
<td>1.8</td>
<td>1000</td>
<td>0.025</td>
<td>0.00025</td>
<td>10000</td>
</tr>
<tr>
<td>$\delta^W$</td>
<td>0.02</td>
<td>34.56</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>211</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>$\eta_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>126</td>
<td></td>
<td>0.53</td>
</tr>
</tbody>
</table>

Cross-price parameters $\alpha_{12}$ and $\alpha_{21}$ are introduced at values of -0.05 or 0.05 and note that in this 2-product case $\alpha_{12} = \alpha_{21}$. This value corresponds to cross-price elasticities at about 10% of the value of the own-price elasticities. Values for $\delta^W$ and $\delta^R$ lie in the range 0.06-0.15.\(^{18}\)

\(^{17}\) The scenarios in Sexton and Zhang are based on $|\varepsilon_1^R| / \eta_1^F \in \{0.5, 1.0, 2.0\}$.

\(^{18}\) Similar to values estimated empirically by Morrison Paul (2001).
A further consideration in operating the model is the value of the output terms $Y_1$ and $Y_2$. At values less than unity, the capacity for the multi-product cost functions (specified in (3) and (4) as $y_1$ and $y_2$) to reflect economies of scope collapses. It is then necessary to specify supply and demand parameters to avoid optimal values of $Y_1$ and $Y_2$ that lie at unity or below.

3.3. Model sensitivity to demand and supply parameter assumptions

The model’s sensitivity to relative values of elasticities was tested with a series of model runs under assumed initial values (detailed in table 1). The results for selected key endogenous variables from case I, across elasticity specifications A-G, are presented in table 2. Table 2 consists of seven corresponding vertically-arrayed repeating blocs (A-G). Results from model runs for combinations of $\Phi_1^R$, $\Phi_2^R$, $\Phi_1^W$, $\Phi_2^W$ under two cross-price demand conditions $\alpha_{12} = \alpha_{21} = 0$ (i.e. no cross price effects) and $\alpha_{12} = \alpha_{21} = -0.05$ (substitution in demand) are presented in each bloc. The top row of each bloc is indexed at 100, and represents the case of perfect competition throughout the model with no interactions in demand or supply.

In the case of supply that is much more elastic than demand (table 2’s bloc A), retail input market power ($\Phi_1^R = 0.4$) raises retail price and lowers processor price for product 1 relative to the perfectly competitive outcome. Output of product 1 declines by 8% (to an index of 92, see second row in the $Y_1$ column). Alternatively, input market power by processors ($\Phi_1^R = 0.4$) leaves all endogenous variables unchanged. A combination of these two scenarios ($\Phi_1^R = \Phi_1^W = 0.4$) has the same effect as $\Phi_1^R = 0.4$ alone. The bottom rows of the top bloc of table 1 indicate that substitution in demand ($\alpha_{12} = \alpha_{21} = -0.05$) magnifies and reverses the impact of market power, and (by construction) affects $Y_2$ and the markets for product 2. Notably, under the conditions $\varepsilon < \eta$ farm-level prices are unaffected by market power in the model, regardless of cross-price influences at consumer demand level.

Bloc B of table 2 presents the specification of $\varepsilon > \eta$ in the model, in an identical series of runs to that in bloc A. In a reversal of bloc A’s results, market power affects upstream prices more than it does downstream prices: $\Phi_1^R = 0.4$ raises retail price by just 1% but lowers processor- and farm-stage prices by 24% each. Product volume declines 25% throughout the model, and the association of this change with the 1% change in retail price is in line with the assumption of relatively elastic consumer de-

19 Models II, III and IV were similarly tested, yielding identical results for shared parameters.
mand. Substitution in demand \((\alpha_{12} = \alpha_{12} = -0.05, \text{ see bottom rows of bloc B})\) magnifies these effects for product 1, and (by construction) reverses them for product 2, throughout the model. The greater magnitude of change in \(Y_1\) and \(Y_2\) relative to changes in retail prices reflects the higher demand elasticity than in bloc A. The substantial difference between blocs A and B is the effect of market power in both markets (products 1 and 2) under substitution in demand, which in bloc A is associated with a 22\% increase in product volume and in bloc B with a 20\% decline (indices of 122 and 80, respectively).

The specification \(\varepsilon = \eta\) is presented in bloc C. Input market power at each stage raises prices at the stage exercising the market power and lowers them at upstream stages, while raising prices at downstream stages. Farm stage prices fall 9\% (index = 91) in response to \(\Phi^R_1 = 0.4\), and fall 5\% in response to \(\Phi^W_1 = 0.4\) and 15\% in response to the combination \(\Phi^R_1 = \Phi^W_1 = 0.4\). At the farm stage these effects are dominated by substitution in demand: the capacity for the system to switch to consumption of \(Y_2\) as market power is exercised over the \(Y_1\) market results in an increase in demand for \(Y_2\), with an associated shift in the demand curve, which in turn feeds back as higher prices for \(Y_1\), to which farmers respond with increased volumes of both \(Y_1\) and \(Y_2\).

Blocs D, E, F and G examine polar cases of elasticity conditions. Bloc D \((\varepsilon \to \infty)\) presents quantities that are substantially affected by market power, in association with rather small changes in retail prices (due to the horizontal nature of the presumed consumer demand curve). This effect is reversed in bloc F \((\varepsilon \to 0)\), as expected, due to a presumed vertical consumer demand curve. Inelastic demand (bloc F) is also associated with substantial impacts of substitution effects on demand, relative to those seen in the absence of substitution. Inelastic supply (bloc G, \(\eta \to 0\)) is difficult to specify in the model, due to scaling problems, and is approximated by \(\eta = 0.53\). However, this case exacerbates price impacts at farm level due to the “vertical” nature of the supply curve, and so conforms to design expectations.
<table>
<thead>
<tr>
<th>Demand and supply conditions</th>
<th>Exogenous variables</th>
<th>Endogenous variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity relations $\alpha_{12} = \alpha_{31}$</td>
<td>$\Phi^R_1$</td>
<td>$\Phi^R_2$</td>
</tr>
<tr>
<td><strong>Bloc A</strong></td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>$\varepsilon &lt; \eta$ ($d\eta = 0.02$)</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>122</td>
<td>122</td>
</tr>
<tr>
<td>Bloc B</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>$\varepsilon &gt; \eta$ ($d\eta = 35$)</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>77</td>
<td>77</td>
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Table 2. (cont’d) Model sensitivity to elasticity specifications

<table>
<thead>
<tr>
<th>Demand and supply conditions</th>
<th>Exogenous variables</th>
<th>Endogenous variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity relations ( \alpha_{12} = \alpha_{21} )</td>
<td>( \Phi_R^1 )</td>
<td>( \Phi_R^2 )</td>
</tr>
<tr>
<td>Bloc C ( \varepsilon = \eta \ (\delta \eta = 1.0) )</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Bloc D ( \varepsilon \rightarrow \infty \ (\varepsilon = 211) )</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
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<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>-0.05</td>
<td>0.40</td>
<td>0.40</td>
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</table>
Table 2. (cont’d) Model sensitivity to elasticity specifications

<table>
<thead>
<tr>
<th>Demand and supply conditions</th>
<th>Exogenous variables</th>
<th>Endogenous variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity relations $\alpha_{12} = \alpha_{21}$</td>
<td>$\Phi^R_1$ $\Phi^R_2$ $\Phi^W_1$ $\Phi^W_2$</td>
<td>$Y_1$ $Y_2$ $P^R_1$ $P^R_2$ $P^W_1$ $P^W_2$ $P^F_1$ $P^F_2$</td>
</tr>
<tr>
<td>Bloc E $\eta \to \infty \ (\eta = 126)$</td>
<td>0.40 0.40</td>
<td>100 100 100 100 100 100 100 100</td>
</tr>
<tr>
<td></td>
<td>-0.05 0.40</td>
<td>92 100 106 100 97 100 100 100</td>
</tr>
<tr>
<td></td>
<td>-0.05 0.40</td>
<td>100 100 106 100 97 100 100 100</td>
</tr>
<tr>
<td></td>
<td>-0.05 0.40</td>
<td>91 100 106 100 97 100 100 100</td>
</tr>
<tr>
<td>Bloc F $\epsilon \to 0 \ (\epsilon = 0.01)$</td>
<td>0.40 0.40</td>
<td>112 123 119 113 105 109 100 100</td>
</tr>
<tr>
<td></td>
<td>-0.05 0.40</td>
<td>111 123 119 113 105 109 100 100</td>
</tr>
<tr>
<td></td>
<td>-0.05 0.40</td>
<td>113 113 120 120 105 105 100 100</td>
</tr>
<tr>
<td></td>
<td>-0.05 0.40</td>
<td>122 122 112 112 109 109 100 100</td>
</tr>
</tbody>
</table>

Innovation in a multiple-stage, multiple-product food marketing chain
Table 2. (cont’d) Model sensitivity to elasticity specifications

<table>
<thead>
<tr>
<th>Demand and supply conditions</th>
<th>Exogenous variables</th>
<th>Endogenous variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity relations $\alpha_{12} = \alpha_{21}$</td>
<td>$\Phi^R_1 \Phi^R_2 \Phi^W_1 \Phi^W_2$</td>
<td>$Y_1 \ Y_2 \ P^R_1 \ P^R_2 \ P^W_1 \ P^W_2 \ P^F_1 \ P^F_2$</td>
</tr>
<tr>
<td>Bloc G</td>
<td>0.40 0.40</td>
<td>100 100 100 100 100 100 100 100</td>
</tr>
<tr>
<td>$\eta \to 0 (\eta = 0.53)$</td>
<td>0.40 0.40</td>
<td>71 100 100 100 46 100 46 100</td>
</tr>
<tr>
<td>-0.05 0.40 0.40</td>
<td>51 100 100 100 46 100 8 100</td>
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</tr>
<tr>
<td>-0.05 0.40 0.40</td>
<td>73 103 105 105 50 105 50 105</td>
<td></td>
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<td>52 103 105 105 50 105 11 105</td>
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<tr>
<td>-0.05 0.40 0.40</td>
<td>73 73 105 105 50 50 50 50</td>
<td></td>
</tr>
<tr>
<td>-0.05 0.40 0.40</td>
<td>73 73 105 105 105 105 50 50</td>
<td></td>
</tr>
</tbody>
</table>
3.4. Scenarios examined and hypotheses to be tested

3.4.1. Market power
The effects of a progression of values for market power are examined, across all four models. The extent to which these effects are offset or exacerbated by interactions in consumer demand (complementarity or substitutability) and costs (economies of scope) is also examined. Finally, scenarios will include the impacts of market power on the generation and transmission of benefits and costs from supply shocks (such as innovation) and demand shocks (income effects or changing tastes).

Our expectation is that researchers’ previous results will be reproduced for the single chain scenarios: that welfare declines as the degree of market power rises. The specified model is better able to track developments in the allocation of welfare under market power scenarios than are previous models because of the inclusion of additional chain stages. It is expected that welfare will accumulate in the stages exercising the market power and be depleted elsewhere, particularly as consumer and producer stages’ price-taking behaviour is enforced by the model.

3.4.2. Product interaction in demand
Consumer demand equations (5) feature parameters enabling substitutability ($\alpha_{12,21} < 0$) and complementarity ($\alpha_{12,21} > 0$) in demand. The impact of these two demand interactions, relative to $\alpha_{12,21} = 0$, will be examined for all model scenario outcomes. This broadens the examination of the impacts of market power to address the importance of relationships between markets: for example the extent to which the effects of market power in one market can be offset throughout the chain by perfect competition in another market; and the extent to which complementarity amongst products can be exploited by market power in one, or two, markets.

The expectation is that substitutability in demand will be associated with increased production, and higher prices, in both chains. The production result arises from the signs in (5), while prices reflect the fact that any price reduction in one product will be accompanied by increased demand (by way of a demand shift), and hence increased price, for the other product and vice versa. These effects will also apply where market power is exercised, becoming most apparent where it is applied across chains (i.e. observing change in chain 1 while market power is exercised in chain 2).
3.4.3. Product interaction in costs

Cost functions (3) and (4) feature potential for economies of scope $\delta^R > 0$ and $\delta^W > 0$ at retail and processing stages, respectively. Examination of the influence of economies of scope includes the identification of interactions between market power and costs conditions: the ways in which firms might combine technologies that feature economies of scope with market power within the food marketing chain.

We expect that economies of scope will result in increased profits at the stage where the economies of scope are applied. However, there may be offsetting factors associated with volume changes throughout the chain. Profit increases may be offset to some extent, for example, by increasing product volumes which drive down retail and other prices by way of (5).

3.4.4. Supply shocks

Farm stage supply functions (2) can feature supply shocks by manipulation of $b_1$, $b_2$. Although this generic approach applies across a range of supply factors (drought, entry and exit from farm production, etc), the application pursued here is innovation. Innovation is modelled as a % reduction in $b_1$. Its impacts are examined in terms of price and production changes, the resulting welfare allocation, and the apparent transmission of prices throughout the chain under a variety of market power specifications. These measures will be examined for their sensitivity to interactions in demand.

Under perfect competition, the farm-level supply shock is expected to be transmitted throughout the chain as price declines and welfare increases, largely due to increased output. This output response will be restricted by the exercise of market power, so that benefits accruing to the farm level of its adoption of an innovation will be restricted by market power. Because of the positive signs in (1) and (2), restricted volume throughout the chains will be associated with reduced prices at farm level that will be offset to some extent by upward price pressure at retail level. However, the exercise of market power is expected to intervene between these effects and extract surplus from the farm level.

Demand interactions are expected to play a significant role in the generation and allocation of benefits from farm-level innovation. Increases in farm production of one product will reduce its price, fuelling increased consumption which is accompanied
by increased consumption of a complementary product but reduced consumption of a substitute.

3.4.5. Demand shocks

Consumer demand equations (5) offer the potential for demand shocks by manipulation of $a_1, a_2$. This generic approach might address a range of subjects (income change, population growth, changes in tastes), and is not pursued in a specific application here. However, the welfare allocation and price transmission effects of the demand shock will be examined under various market power scenarios and for their sensitivity to interactions in demand and cost.
4. General results

4.1. Market power in the absence of product interactions

In the absence of economies of scope and cross-price effects in demand, the model operates essentially as two independent single-product food marketing chains. This section reports impacts of combinations of market power up and down the (single) chain for product 1.

4.1.1. Impacts on output

Figure 1 presents the impacts of selected combinations of market power in food marketing chain 1 on output $Y_1$. As expected, all forms and combinations of market power cause output to decline, and the declines are somewhat convex in the magnitude of market power (0 representing perfect competition and 1 representing monopoly and/or monopsony). Of the cases presented, the smallest declines in output are associated with exercise of market power at just one point on the chain (lines 1-4), and the exercise of market power on output markets appears to impact output more than does its exercise on input markets (although it is notable that some of the lines cross between market power values of zero and one). Owing to the specification of the model, exercise of sequential output and input market power has the same impact whether at retail or processing stage (see lines 5 and 6, respectively). The mix of retail and processing monopoly is shown to reduce modelled output by up to 60% (line 8), relative to perfect competition, whereas the mix of retail and processing monopsony (line 7) reduces output by up to 40%.

\[
\frac{\partial^2 c_1}{\partial y_1 \partial y_2} = \frac{\partial^2 c_2}{\partial y_2 \partial y_1} = 0 \text{ in (3) and (4).}
\]

\[
\alpha_{12} = \alpha_{21} = 0 \text{ in (5).}
\]
4.1.2. Impacts on total welfare

Welfare in food marketing chain 1 (see figure 2) declines monotonically as market power rises, across the same seven forms and combinations of market power as examined in the previous section. The ranking of welfare impacts of the eight forms of market power is the same as that for output (see above), but the relationships appear concave in market power rather than convex as above, and the magnitude of impacts is not as severe.
4.1.3. Impacts of market power on welfare allocation

At model solution values, perfect competition results in an allocation of welfare amongst food marketing chain participants of 45% to consumers, 19% each to retail-
ers and processors, and 17% to farmers (see left hand bar in figure 3). There is no in-
ference associated with those simulated values: rather, interest centres on how they
change in the model runs. Figure 3 presents the same eight market power influences
as above, with the magnitude of market power set at 0.6 in each case. In all cases,
market power shifts welfare toward the agent exercising it, at the expense of all other
agents, but particularly at the expense of the agents upon whom the market power is
exercised.

The agents incapable of exercising market power (consumers and farmers) are worse
off under any market power scenario than under perfect competition. Figure 2 above
showed that welfare declines as a consequence of the exercise of market power, and
the shares of the reduced overall welfare are seen in figure 3 to be highly sensitive to
the form market power takes. Single manifestations (bars 1-4) of market power have less effect than multiples (bars 5-8). The worst scenario for both consumers and farmers is the case of $\Theta_1^R = \Theta_1^W = 0.6$ (i.e. output market power exercised by both retailers and processors). This scenario also reduces output and total welfare by the most (see figures 1 and 2).

**Figure 3. Shares of total welfare under selected market power scenarios**

![Diagram showing shares of total welfare under selected market power scenarios]

<table>
<thead>
<tr>
<th>Market power scenario (intensity = 0.6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfect Competition</td>
</tr>
<tr>
<td>% of total welfare</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

### 4.2. Market power and product interactions

#### 4.2.1. Demand interactions

The model generates different solutions under various assumptions about demand interactions. Figure 4 presents output and price solutions under perfect competition: as the model is symmetric in the absence of (asymmetric) market power exercise, values for the two chains are identical.

Substitutability in consumer demand ($\alpha_{12}, \alpha_{21} < 0$ in (5)) provides for higher production levels, and higher prices throughout the chain than does independence in con-
sumer demand ($\alpha_{12}, \alpha_{21} = 0$). The opposite is true for complementarity ($\alpha_{12}, \alpha_{21} > 0$). This result arises because the optimal choice of $Y_1$ generated by the model takes into account not only the prices in the chain for product 1, but also for product 2, and the converse applies to the effects of chain 2 choices on chain 1. The mechanism of this influence is shown in (13) and (14), such that demand parameters shift to accommodate $\alpha_{12}, \alpha_{21}$, with an effect dependent on sign (i.e. substitution or complementation). The extent of the divergence between solutions also depends on market power (see figure 5), due to the impact of $\varepsilon_{21}^R$ in (9) as discussed earlier.

**Figure 4. Baseline solutions under perfect competition**

![Bar chart showing baseline solutions under perfect competition](image)
The impact of asymmetric (between the two chains) application of market power is presented in figure 6. Relative to respective perfectly competitive solutions (index = 100), both output and welfare in chain 1 rise due to the exercise of market power in chain 2 (in this case processor’s input market power), where products 1 and 2 are substitutes in demand at consumer level. Where products 1 and 2 are complements in demand, these variables decline steadily with increasing levels of market power. It should be noted that the single-chain welfare and output effects are symmetric around 100 (the perfectly competitive levels). Under monopsony in chain 2, welfare in chain 1 is at index 103 where \( Y_1 \) and \( Y_2 \) are substitutes and 97 where they are complements. However, the total welfare (the sum of welfare in chains 1 and 2, denoted by lines with boxes in figure 6) behaves differently: the monopsony case with substitution delivers a result of about index 101, whereas complementarity delivers index 96.5.
Clearly, the exercise of market power in one chain can be offset by agents in the food marketing chain switching to products traded under perfectly competitive conditions. The model results suggest that this can be done with an overall gain in welfare. Complementarity in consumer demand restricts such substitution and exacerbates the welfare losses associated with the exercise of market power.

The allocation of welfare within the two chains remains independent of consumer demand cross-product specification (see table 3). Under perfect competition, both
chains allocate welfare identically, as seen earlier. Market power in chain 2 (the case presented here is $\Phi_2^{W} = 0.6$) shifts allocation in favour of the food chain participant exercising the market power, at the expense of the others. The pattern of this allocation shift is independent of the form of consumer demand interaction.
Table 3. Allocation of welfare with cross-product exercise of market power

<table>
<thead>
<tr>
<th>Stage</th>
<th>Perfect competition</th>
<th>$\Phi_2^W = 0.6$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Independence in demand</td>
<td>Substitution</td>
</tr>
<tr>
<td></td>
<td>Chain 1</td>
<td>Chain 2</td>
</tr>
<tr>
<td>Consumer</td>
<td>45%</td>
<td>45%</td>
</tr>
<tr>
<td>Retailer</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Processor</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Farmer</td>
<td>17%</td>
<td>17%</td>
</tr>
</tbody>
</table>

4.2.2. Cost interactions

The model generates solutions concerning the application of economies of scope by either or both of retailers (via $\delta^R$) and processors (via $\delta^W$). As a cost reduction (see (3) and (4)), economies of scope are associated with output increases regardless of where they occur in the food marketing chain (left-most bar of each set of bars in figure 7). Economies of scope are also unambiguously associated with welfare increases. Note that these changes occur symmetrically in both chains, so figure 7 presents only the results from chain 1.

A puzzling result is the relative size of price changes associated with economies of scope. Retail price falls as a consequence of the scope economies, due to their output-increasing effect: the same principle applies to all prices downstream of the chain participant employing the economies of scope. However, this output increase is also associated with higher costs at farm level, which in turn raise the purchasing prices throughout the chain. The overall result is that the food marketing chain participant that employs technology with economies of scope ends up facing reduced selling prices and increased purchasing prices.
This result raises two questions concerning (i) the model mechanism delivering it and (ii) its practical significance in the context of observed use of multi-product technologies in the food industry. The result arises from the model’s use of positive supply elasticities at farm level (based on $\beta_1$ and $\beta_2$), and at processor level (the term $\eta_{11}W$ and $\eta_{22}W$ in (9)). These are unambiguously positive in sign (see mathematical appendix (i) for derivation from each of models I-IV), and have a magnitude that is highly sensitive to $\delta$. The economic interpretation of the nature of these elasticities is that higher volumes are associated with higher costs and prices, and that economies of scope can act as an accelerator of that effect. This is in contrast to retail price formation in the model, which depends on demand parameters and output (see (13)): although output is cost-dependent (via profit maximisation), retail price formation in the model may be being excessively driven by the demand parameters.

Beyond the mathematical construction that leads to the result, some lessons emerge. Much conventional wisdom suggests that price formation is dominated by consumer demand issues rather than costs and technology. The extent to which the result achieved here reflects that wisdom is unclear. A second consideration is whether such
volume-driven adjustments actually happen in the real world: perhaps actual cost interactions do not bring forth volume increases; or alternatively firms act so as to eliminate them. This latter explanation can be examined using the model. In particular, runs of the model examine the relative profitability of employing economies of scope in the presence and absence of market power.

Figure 8 presents six runs of the model, labelled 1-6, that show the impact of increasing levels of processors’ market power in the absence and presence of economies of scope. In perfect competition, the use of technologies exhibiting economies of scope unambiguously reduces processors’ profits. Increased input market power by processors serves to narrow the difference between “scope” and “no scope” scenarios, but at all levels of input market power profits using “scope” lie below those using “no scope” (see run 1 c.f. 2, as green lines). In two other cases (output market power – runs 3 and 4 - and combined input and output market power – runs 5 and 6), there appears a level of market power at which “crossover” occurs: above that level of market power it is more profitable for processors to employ the technology using economies of scope. For processors’ output market power, the crossover level of market power is about 0.6, while for the combined market power it lies at about 0.4.

If it is the case that profitable use of economies of scope technologies requires the exercise of market power, then the question that arises is whether the form of the market power affects the result. Figure 9 presents six models runs in which retailers exercise various levels of market power and processor profits are observed for use of “scope” technologies (runs 8, 10 and 12) and “no scope”. In no case is a “crossover” result observed, but rather processors’ profits under “scope” scenarios diverge in proportion to the extent of retailers’ market power. This outcome indicates that the synergy between market power and economies of scope technologies is based on the costs faced by firms at the stage at which economies of scope are applied: it is not enough to simply restrict output; the manner of the restriction must reflect profit maximisation.
Figure 8. Interaction between market power and economies of scope

Innovation in a multiple-stage, multiple-product food marketing chain
4.3. A demand shock as a model application

The introduction of a demand shock to the model is managed via a fixed-% increase in $a_1$ in (5). Table 4 presents, in the top panel, the price changes resulting from a 20% increase in $a_1$ (geometrically, a rightward shift of the demand curve for product 1). These vary according to the degree and form of market power exercised, with examples showing retailer market power. Retailers’ input or output market power, and particularly the combination of both, have the effect of exacerbating retail price increases and restricting other price increases resulting from the demand shock.

The bottom panel of table 4 presents measures related to transmission of price changes: the ratio of price changes at the different stages of the chain. Under perfect
competition, 95% of a retail price change as a consequence of a demand shock is passed to the processor. In turn, 87% of that change is passed to the farmer. Overall, 83% of any retail price change is passed to the farmer. Transmission is significantly reduced by the exercise of market power. The whole-chain transmission is reduced to 73% in the case of retail power on input and output markets, with the greatest changes being in retail-to-processing transmission.

Table 4. Price changes and transmission during demand shock

<table>
<thead>
<tr>
<th></th>
<th>Perfect Competition</th>
<th>$\Phi^R_1 = 0.6$</th>
<th>$\Theta^R_1 = 0.6$</th>
<th>$\Phi^R_1 = \Theta^R_1 = 0.6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>price changes due to demand shock</td>
<td>Retail stage</td>
<td>19%</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>Processor stage</td>
<td>18%</td>
<td>18%</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td>Farm stage</td>
<td>16%</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>extent of transmission of price</td>
<td>Retail to farm</td>
<td>0.83</td>
<td>0.78</td>
<td>0.77</td>
</tr>
<tr>
<td>changes throughout the chain</td>
<td>Processor to farm</td>
<td>0.87</td>
<td>0.85</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>Retail to processor</td>
<td>0.95</td>
<td>0.92</td>
<td>0.91</td>
</tr>
</tbody>
</table>
5. **Innovation as a model application**

Innovation is modelled as a (50%) reduction in $b_1$ in (1) and (2), which is geometrically interpreted as a rightward shift in the farm supply curve for product 1. The shift is equivalent to a reduction in fixed costs, but associated volume adjustments at farm stage, and beyond, serve to impact variables costs as well. These adjustments are discussed below in the context of the exercise of market power and its effect on price-quantity interactions.

5.1. **Innovation and market power in a single chain**

5.1.1. **Perfect competition**

The 50% reduction in $b_1$ in (1) and (2) under perfect competition and without demand interactions between the two products, results in a 2.8% increase in $Y_1$ (see first row, first column of table 5). Under those conditions, the overall decline in farm-level costs is 15.8% (third row of table 5). The welfare change associated with the farm-level innovation (see bottom row of table 5) is a 2.8% increase, and stakeholders at each stage of the food marketing capture a 5.6% increase in chain 1, which when averaged with the unchanged welfare in chain 2, provides a 2.8% increase.

The price changes associated with the farm-level innovation are presented in table 6, in which the case of perfect competition and no product demand interactions is featured in the first column. The 15.8% decline in farm level costs (see table 5) for $Y_1$ brings about a 2.1% decline in consumer prices, a 4.3% decline in processors prices, and a 10.2% decline in farm-stage prices: note that no change occurs for $Y_2$. The transmission of farm cost savings for $Y_1$ through to price reductions throughout the chain is presented in the bottom panel of table 7. The 15.8% decline in farm costs is transmitted at a rate of 13% to retail level prices, 27% to processing level prices, and 65% to farm level prices.\(^{22}\)

Table 8 presents the changes in shares of welfare accruing to each stage of the chain as a result of the farm-level innovation. The zero values in the left hand column indicate that under perfect competition, there is no change in those shares.

\(^{22}\) Cost-to-price transmission coefficients do not sum to 100% because changing volumes affect costs so that some farm-level costs are passed on as costs at downstream changes.
5.1.2. Market power

The second, third and fourth columns of tables 5-8 present the results of simulations of farm-level innovation under perfect competition (discussed above) and scenarios for the exercise of market power. The cases presented all refer to processors’ market power,\(^{23}\) being (*ceteris paribus*):

- processors’ input market power in chain 1 \((\Phi_1^W = 0.6)\);
- processors output market power in chain 1 \((\Theta_1^W = 0.6)\); and
- processors input and output market power in chain 1 \((\Theta_1^W = \Phi_1^W = 0.6)\).

The increase in output \(Y_1\) associated with the innovation is 2.8% under all market power scenarios. It should be noted that this comparison involves only the innovation: market power applies both with and without the innovation. The cost decline at farm level is 17-21%, and is greatest when market power applies to both input and output markets. As is the case for perfect competition, cost changes reflect volume changes, and as processors increasingly restrict volumes of \(Y_1\) by exercising market power, farm costs fall due to these low volumes. Under all market power scenarios, farm-level innovation increases welfare but the magnitude of this change is slightly reduced as market power is applied more widely (a 2.6% increase under \(\Theta_1^W = \Phi_1^W = 0.6\), compared to a 2.8% increase under perfect competition. Under a given market power scenario, shares of aggregate welfare are unaffected by the innovation. However, the innovation delivers different welfare allocations under different market power scenarios (see table 8).

Market power substantially affects the patterns of price change arising from farm level innovation. The reduction in processors’ prices declines as they apply market power more widely. As a consequence, retail prices (being downstream from processors’) also decline less than they do under perfect competition but the effect is less pronounced than is the case for processors’ prices. Retail prices changes are influenced by the impacts of market power: restricted quantities drive up retail prices (see (5)) and offset other effects.

Conversely, farm level prices decline by rather more when subjected to market power than they do under perfect competition. This is the consequence of several separate effects: increasingly restricted output due to input and output market power by proc-

\(^{23}\) Other locations, forms and intensities of market power were examined, and results correspond to the patterns reported here. Further information on specific combinations and forms of market power are available from the authors.
cessors reduce farm-level costs and hence prices according to the pricing rule (12); and the cost reduction associated with the innovation reinforces the decline in farm-level prices.

The transmission of innovation-generated farm cost savings to prices throughout the chain is also influenced by market power (see table 7). Transmission to retail prices falls as low as 0.05, and to processing prices 0.09 (from 0.13 and 0.27 respectively under perfect competition). For scenarios involving market power, much of the transmission of cost savings into prices occurs at farm level, and this effect is greatest when market power is exercised elsewhere in the chain.

Shares of change in aggregate welfare due to the farm-level innovation are greatly affected by the exercise of market power (see table 8). For the scenarios of processors’ market power shown, processors’ shares of the welfare generated by the innovation increase by up to 1.4%, while at all other stages welfare shares decline with increasing incidence of market power.

5.1.3. Demand interactions

Tables 5-8 feature three horizontally-arrayed panels, each referring to a state of consumer demand interaction: no interaction (the left hand panel used above to discuss the perfectly competitive and market power cases); substitution (seen in the middle panel of tables 5-8); and complementarity (the right hand panels).

Comparison of the effects of consumer demand interactions begins with the left hand column of each of the three panels in table 5. The innovation at farm level in chain 1 generates a 2.8% increase in \( Y_1 \) under perfect competition (as discussed above). Where \( Y_1 \) and \( Y_2 \) are substitutes in demand, the effect on \( Y_1 \) is reduced (to a 2.3% increase) and accompanied by a decline in \( Y_2 \) (of 0.3%). Equal and opposite effects are observed on \( Y_1 \) and \( Y_2 \) where \( Y_1 \) and \( Y_2 \) are complements in demand. The greatest increase in total welfare is available where innovation takes place in the presence of complementarity in demand (a 3.5% welfare increase from the innovation, as opposed to 2.1% with substitution and 2.8% with independent consumer demand functions). By construction, changes in \( Y_2 \) and prices and welfare in the product chain for product 2 are observed only where the demand interaction parameters are non-zero.

The observed opposite effects of complementarity and substitution in consumer demand are due to the system’s reactions to price changes. The cost reduction induced
at farm level (14.4% under substitution and 17.0% under complementarity) lie below and above, respectively, the 15.8% cost reduction associated with the farm-level innovation under independent demand conditions. Taking substitution (the middle panel of table 6) as an example, the farm-level cost reduction provides a “rightward shift in the supply curve for $Y_1$”, increasing volume throughout the system. At retail level, this volume increase for $Y_1$ forces prices downwards for $Y_1$ but “shifts the demand curve” for $Y_2$ to the left. This reduces the volume of $Y_2$ throughout the system, which at farm level is associated with a decline in both price and cost for $Y_2$. An analogous set of reasoning explains the complementarity results.

5.1.4. **Consumer demand interactions and market power**

The combined effects of market power and interactions in consumer demand in determining the impact of a farm-level innovation can be observed by traversing each of the three panels in table 5 (the left panel features independence in consumer demand). Both substitutability and complementarity dampen the effects of market power on the impacts of farm level innovation. This effect is due to the impacts of the volume restrictions associated with the exercise of market power in chain 1, and the associated adjustment to, and feedbacks from, chain 2. Taking complementarity (the right panel of table 5) as an example, more restricted volumes of $Y_1$ (i.e. a 3.0% increase rather than 3.1% increase under perfect competition, due to the innovation) mean that $Y_1$’s price reduction (see first row of table 6) is lower than that under perfect competition (1.3% c.f. 2.1%). The associated rightward shift of the demand curve for $Y_2$ is therefore smaller than under perfect competition, and all associated changes in product chain 2 reflect this result. The case where a firm exercises market power in both product chains simultaneously is presented below.
### Table 5. Impacts of farm-level innovation: welfare effects

<table>
<thead>
<tr>
<th>Demand conditions</th>
<th>Independent consumer demand</th>
<th>Substitution in consumer demand</th>
<th>Complementarity in consumer demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfect competition</td>
<td>(\Phi_I = 0.6)</td>
<td>(\Theta_I = 0.6)</td>
<td>(\Theta_I = 0.6)</td>
</tr>
<tr>
<td>(Y_1)</td>
<td>2.8%</td>
<td>2.8%</td>
<td>2.8%</td>
</tr>
<tr>
<td>(Y_2)</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>(C_1)</td>
<td>-15.8%</td>
<td>-17.0%</td>
<td>-20.1%</td>
</tr>
<tr>
<td>(C_2)</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>(CS_1)</td>
<td>5.6%</td>
<td>5.6%</td>
<td>5.6%</td>
</tr>
<tr>
<td>(CS_2)</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>(\pi_1^R)</td>
<td>5.6%</td>
<td>5.6%</td>
<td>5.6%</td>
</tr>
<tr>
<td>(\pi_2^R)</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>(\pi_1^W)</td>
<td>5.6%</td>
<td>5.6%</td>
<td>5.6%</td>
</tr>
<tr>
<td>(\pi_2^W)</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>(PS_1)</td>
<td>5.6%</td>
<td>5.6%</td>
<td>5.6%</td>
</tr>
<tr>
<td>(PS_2)</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Total welfare</td>
<td>2.8%</td>
<td>2.8%</td>
<td>2.7%</td>
</tr>
</tbody>
</table>
### Table 6. Impacts of farm-level innovation: prices and costs

<table>
<thead>
<tr>
<th>Demand conditions</th>
<th>Independent consumer demand</th>
<th>Substitution in consumer demand</th>
<th>Complementarity in consumer demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfect competition</td>
<td>$\Phi_1^W = 0.6$</td>
<td>$\Theta_1^W = 0.6$</td>
<td>$\Theta_1^W = 0.6$</td>
</tr>
<tr>
<td>Endogenous variable</td>
<td>change due to the innovation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_1^R$</td>
<td>-2.1%</td>
<td>-1.8%</td>
<td>-1.2%</td>
</tr>
<tr>
<td>$P_2^R$</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>$P_1^W$</td>
<td>-4.3%</td>
<td>-3.4%</td>
<td>-2.2%</td>
</tr>
<tr>
<td>$P_2^W$</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>$P_1^F$</td>
<td>-10.2%</td>
<td>-11.2%</td>
<td>-13.6%</td>
</tr>
<tr>
<td>$P_2^F$</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>$c_1^F$</td>
<td>-15.8%</td>
<td>-17.0%</td>
<td>-20.1%</td>
</tr>
<tr>
<td>$c_2^F$</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
### Table 7. Impacts of farm-level innovation: price transmission

<table>
<thead>
<tr>
<th>Demand conditions</th>
<th>Independent consumer demand</th>
<th>Substitution in consumer demand</th>
<th>Complementarity in consumer demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \Phi_1^W = 0.6 )</td>
<td>( \Phi_1^W = 0.6 )</td>
<td>( \Phi_1^W = 0.6 )</td>
</tr>
<tr>
<td>Perfect competition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Phi_1^W = 0.6 )</td>
<td></td>
<td>( \Theta_1^W = 0.6 )</td>
<td>( \Theta_1^W = 0.6 )</td>
</tr>
<tr>
<td>Transmission of change in ( c_i^R ) to prices</td>
<td>extent of transmission of cost change (due to innovation) through to prices throughout the chain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( p_1^R )</td>
<td>0.13</td>
<td>0.13</td>
<td>0.14</td>
</tr>
<tr>
<td>( p_2^R )</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.02</td>
</tr>
<tr>
<td>( p_1^W )</td>
<td>0.20</td>
<td>0.68</td>
<td>0.66</td>
</tr>
<tr>
<td>( p_2^W )</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.02</td>
</tr>
<tr>
<td>( p_1^F )</td>
<td>0.65</td>
<td>0.68</td>
<td>0.66</td>
</tr>
<tr>
<td>( p_2^F )</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.01</td>
</tr>
</tbody>
</table>
Table 8. Impacts of farm-level innovation: shares of welfare

<table>
<thead>
<tr>
<th>Demand conditions</th>
<th>Independent consumer demand</th>
<th>Substitution in consumer demand</th>
<th>Complementarity in consumer demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \Phi_W = 0.6 )</td>
<td>( \Phi_W = 0.6 )</td>
<td>( \Phi_W = 0.6 )</td>
</tr>
<tr>
<td>Perfect competition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Theta_1^W = 0.6 ) ( \Theta_1^W = 0.6 ) ( \Theta_1^W = 0.6 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in share of profits</td>
<td>Consumer</td>
<td>Retailer</td>
<td>Processor</td>
</tr>
<tr>
<td></td>
<td>0.0% -0.3% -0.7% -0.9%</td>
<td>0.0% -0.2% -0.7% -0.8%</td>
<td>0.0% 0.7% 1.3% 1.4%</td>
</tr>
<tr>
<td></td>
<td>-0.3% -0.7% -0.9%</td>
<td>-0.7% -0.8%</td>
<td>1.2% 1.3%</td>
</tr>
<tr>
<td></td>
<td>-0.7% -0.9%</td>
<td>-0.8%</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

Change in share of welfare as a result of innovation

- Consumer: 0.0% -0.3% -0.7% -0.9%
- Retailer: 0.0% -0.3% -0.7% -0.9%
- Processor: 0.0% 0.7% 1.3% 1.4%
- Farmer: 0.0% -0.3% -0.7% -0.9%
5.2. Innovation and market power in multiple chains

5.2.1. Welfare generation from a farm-level innovation

Table 9 presents the results of simulations where market power is exercised by processors in chain 1 alone, chain 2 alone, and then in both chains simultaneously. The exercise is repeated for substitution (the middle panel) and complementarity (the right hand panel), as well as independence in demand (the left hand panel). The left hand panel results are trivial in the sense that the chain 1 impacts of the farm-level innovation in chain 1 are not transmitted to chain 2 at all.

Welfare is substantially reduced by the exercise of market power in both chains simultaneously, with larger impacts under substitution and complementarity in consumer demand than under independent demand. A notable result is that under substitution, market power in chain 2 alone can actually raise the benefits delivered by the farm-level innovation in chain 1 (welfare index of 107 relative to 102 under perfect competition). This result is due to the ability of agents in chain one to substitute into chain 1, thus exacerbating the welfare impacts of the innovation. The reductions in $Y_2$ are due to both effects.

Complementarity works in the other direction (welfare index of 93 as opposed to 96 under perfect competition), due to interaction of two effects:
- the increase in $Y_2$ to accompany the increase in $Y_1$ due to the innovation in chain 1; and
- the reduction in $Y_2$ due to market power in chain 2.

5.2.2. Welfare distribution

Table 10 presents information about the shares of welfare generated in the two product chains. Under perfect competition, the processor receives around 19% of the welfare generated in both product chains. This share increases to around 40% when processors exercise market power in one or another chain, and to about 60% when market power is exercised simultaneously in the two chains.

Under perfect competition, the welfare share accruing to processors is unchanged by the innovation at farm level in chain 1. However, the exercise of market power by processors influences the allocation of the benefits of the innovation. It is notable that when market power is applied simultaneously and at the same level of intensity in
chain 1 and chain 2, shares of the benefits accruing to each chain participant are unaffected. This is because the symmetric application of market power removes the incentive for substitution and/or complementarity.
Table 9. Innovation impacts under multiple market power specifications: allocation of welfare

<table>
<thead>
<tr>
<th>Demand conditions</th>
<th>Independent consumer demand</th>
<th>Substitution in consumer demand</th>
<th>Complementarity in consumer demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Phi_W ) = ( \Phi_1 ), ( \Phi_2 ) = ( \Theta_1 )</td>
<td>( \Phi_W ) = ( \Phi_1 ), ( \Phi_2 ) = ( \Theta_1 )</td>
<td>( \Phi_W ) = ( \Phi_1 ), ( \Phi_2 ) = ( \Theta_1 )</td>
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</tr>
<tr>
<td>Perfect competition</td>
<td>( \Theta_W = 0.6 )</td>
<td>( \Theta_W = 0.6 )</td>
<td>( \Theta_W = 0.6 )</td>
</tr>
<tr>
<td>Change in-output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Y_1 )</td>
<td>2.8%</td>
<td>2.8%</td>
<td>2.8%</td>
</tr>
<tr>
<td>( Y_2 )</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Total welfare (chain 1)</td>
<td>21.7</td>
<td>19.3</td>
<td>21.7</td>
</tr>
<tr>
<td>Total welfare (chain 2)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total Welfare</td>
<td>21.7</td>
<td>19.3</td>
<td>21.7</td>
</tr>
<tr>
<td>Index of Total Welfare</td>
<td>100</td>
<td>89</td>
<td>100</td>
</tr>
</tbody>
</table>
## Table 10. Innovation impacts under multiple market power specifications

<table>
<thead>
<tr>
<th>Demand conditions</th>
<th>Independent consumer demand</th>
<th>Demand conditions</th>
<th>Substitution in consumer demand</th>
<th>Demand conditions</th>
<th>Complementarity in consumer demand</th>
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</thead>
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<tr>
<td></td>
<td>$\Phi_1^W$ =</td>
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<td>$\Phi_1^W$ =</td>
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<tr>
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<td>$\Phi_2^W$ =</td>
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<td>$\Phi_2^W$ =</td>
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<tr>
<td></td>
<td>$\Theta_1^W$ =</td>
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<td>$\Theta_1^W$ =</td>
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<tr>
<td></td>
<td>$\Theta_2^W$ =</td>
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<td>$\Theta_2^W$ =</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perfect competition</td>
<td>$\Omega_1^W = 0.6$</td>
<td></td>
<td>$\Omega_1^W = 0.6$</td>
<td></td>
<td>$\Omega_1^W = 0.6$</td>
</tr>
<tr>
<td></td>
<td>$\Omega_2^W = 0.6$</td>
<td></td>
<td>$\Omega_2^W = 0.6$</td>
<td></td>
<td>$\Omega_2^W = 0.6$</td>
</tr>
</tbody>
</table>

### Processors' share of chain benefits

<table>
<thead>
<tr>
<th>Without innovation</th>
<th>With innovation</th>
<th>Share of total chain benefits held by processors with/without the innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.9%</td>
<td>18.9%</td>
<td>18.9%</td>
</tr>
<tr>
<td>37.8%</td>
<td>38.8%</td>
<td>38.8%</td>
</tr>
<tr>
<td>37.8%</td>
<td>37.2%</td>
<td>62.2%</td>
</tr>
<tr>
<td>58.9%</td>
<td>58.9%</td>
<td>62.2%</td>
</tr>
<tr>
<td>56.6%</td>
<td>37.1%</td>
<td>37.1%</td>
</tr>
</tbody>
</table>

### Stage

<table>
<thead>
<tr>
<th>Change in shares of benefits of the innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer</td>
</tr>
<tr>
<td>Retailer</td>
</tr>
<tr>
<td>Processor</td>
</tr>
<tr>
<td>Farmer</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Change in shares of benefits of the innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer</td>
</tr>
<tr>
<td>Retailer</td>
</tr>
<tr>
<td>Processor</td>
</tr>
<tr>
<td>Farmer</td>
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</tbody>
</table>
6. Discussion and conclusions

6.1. Overview

This paper presents the structure and content of, and selected results from, a model of the food marketing chain. It follows methods developed by various authors based on work by Gardner (1975), as presented in the context of market power by Sexton and Lavoie (2001) and extended to three industry stages by Sexton and Zhang (2001). The current paper provides an advance on that work by introducing multiple products, amongst which the facility exists for interactions in technologies (economies of scope) and demand (substitutability and complementarity). The work done includes solving the model algebraically and implementing it using simple spreadsheets, supplementary checking for internal consistency and against results generated in other software. A small selection of results is presented in this report.

The model reproduces single-chain results delivered by previous authors, including the sensitivity of solutions to the absolute and relative magnitudes of farm supply and consumer demand elasticities. Specification and simulation of cross-chain market power scenarios are easily dealt with and provide new results to complement past authors’ work. The impacts of consumer demand interactions are clear, and easily expli- cable in terms both of mathematical specification and the underlying economic forces at work. The simulated impacts of cost interactions in the chain are less easily explained, but they do generate useful economic information about the nature of linkages between stages and between product chains.

6.2. Principal results

6.2.1. Starting values

The model is sensitive to initial specifications of supply and demand parameters, which in the current work are the raw input to specification of elasticities. Extreme specifications are associated with some extreme results, particularly where multiple effects (market power and demand interactions) are specified together. Following previous authors, the simulations used for actual research employed elasticity values such that (i) they lay within “normal” bounds of magnitude and (ii) were approximately equal in magnitude and opposite in sign. Other issues of starting values included the output values’ needing to be significantly above unity due to the form of cost functions used.
6.2.2. Market power

The model’s results show that increasing levels of market power in the food marketing chain reduce output throughout the chain, in a relationship that is convex in market power and more extreme as the number and forms of market power exercised are increased. The same is true for the impact of market power on total welfare, except that the relationship with market power is concave.

The model quantifies the extent to which welfare shares are changed due to the exercise of market power. In particular, it allows calculation of surplus accumulated at the stage exercising the market power and surplus lost elsewhere in the chain, in each chain. Farmers and consumers are hurt most by (sequential) output market power exercised by processors and retailers, although any form of sequential market power greatly reduces the share of welfare accruing to these stakeholders.

6.2.3. Demand interactions

Substitution (and complementarity) in consumer demand has a substantial effect on the results generated by the model. The capacity for chain stakeholders to switch between chains in response to (i) price changes in one chain and (ii) the exercise of market power in one or both chains, greatly affects the simulation results. Under perfect competition, for example, substitutability and complementarity alter equilibrium prices and volumes in both chains. This is due to the changed profitability relationships at the margin: an additional unit of output now has value in both chains rather than just one.

6.2.4. Cost interactions

Against expectations, the model solution indicates that firms employing technologies featuring economies of scope reduce their profits under perfect competition. The reason is that increased volumes throughout the system raise purchase prices and so raise costs by more than revenues. This effect can be offset by the exercise of market power: restricting volume can also help to control costs. Model results might be tabulated to identify certain critical values for market power, above which economies of scope technologies are profitable. Notably, such critical values appear only in the case where the same stage exercises market power and employs the economies of scope.
6.2.5. Demand shocks

The impacts of a demand shock (e.g. changes in income or tastes) occur differently, depending on the market power being exercised in the chain. As the magnitude and incidence of market power increases, the extent to which price changes are transmitted throughout the chain is reduced, and so the benefits of such a demand shock are able to be accumulated by the stage of the chain exercising the market power. These results are consistent with hypotheses.

6.2.6. Innovation

A farm level innovation generates benefits throughout the food marketing chain. That benefit is greater where complementarity in consumer demand occurs with a related product, and less, where the demand interaction features substitutability. Price transmission within the chain, and between chains, is more pronounced under demand complementarity, and less pronounced under substitution specifications.

Price transmission, and the transmission of cost reductions through to price reductions, is substantially reduced by the exercise of market power. The exercise of market power in the same chain as that in which the innovation occurs enables firms at one stage of the marketing chain to appropriate the benefits of innovation from other stages. This effect is more pronounced where the products in the respective chains are complements in demand, as substitutability allows the market participants to switch to the other chain. A similar effect is observed where the market power is applied in the other chain (not the one in which innovation occurs): in that case the other food chain participants can benefit fully from the innovation as well as being able to substitute away from the product being subjected to the exercise of market power.

6.3. Implications for industry

The model’s results indicate the significant potential for interactions between product chains in the development of marketing and production plans, as well as a role for the exercise of market power. First, marketing of a range of products that are complements appears to be associated with higher prices and volumes throughout the chain than is the case with either substitutes, or ranges of goods that are independent in demand. Where market power is applied, however, output declines most rapidly where product ranges are connected by substitutability, so accelerating the impacts of market power. Exercise by a firm of market power in just one of many chains, however, can
offset any gains to the firm because other chain participants can simply substitute away from the market power. The opposite applies to complementarity. It is clear that benefits flowing to firms from the exercise of market power, and other food chain issues, depend strongly on relationships between markets. It is suggested that effort by firms (e.g. promotion) can change these relationships between products on the markets: this may be an effective way of countering market power, or of increasing the benefits available from its exercise.

Where firms can apply market power across a range of products (e.g. in the setting of a supermarket) they are more likely to benefit from the market power where the products are complements. In fact this is observed in the one-stop, convenience-oriented stance of supermarkets. Similarly, food processors’ market power in one or more of a range of products is likely to pay off only where the products are complements. This may be a factor in brand management, in that market segmentation must be approached with care so as to prevent substitution between the processing firm’s brands.

The model’s results are strongly characterised by simultaneity: price and volume movements throughout the chain are influenced by a variety of factors (internal and external to the model) that together deliver a solution. Economies of scope are a case in point, with the surprising result that they deliver benefits elsewhere in the chain where they are applied, unless market power can be exercised to restrict adjustments of product volume. Although this result should be treated with caution, it is notable that economies of scope might be observed to be best utilised by very large firms, that also appear to exercise the most market power. It is also notable that product diversification by food processing firms is often associated with their past accumulation of market power: the Danish co-operative food processors being a case in point. The existence of “critical values” of market power for the profitability of scope-related technologies is an interesting consideration for firms seeking to make investments in such technologies.

Under the own-price farm supply and consumer demand elasticity assumptions maintained, farm-level innovation appears to generate benefits to farmers and consumers, irrespective of the exercise of market power in the chain and the demand interactions that exist between chains. However, it is clear that the exercise of market power allows other stages of the chain to appropriate these benefits. The model does not identify a level of market power at which farmers would fail to benefit from an innovation, but because innovation is costly, market power may well restrict innovation. Although the entire chain benefits from innovation (due to mark-up pricing) firms that
are capable of exercising market power may find it most profitable to appropriate the benefits of a reduced level of innovation than to share the benefits under perfect competition.

6.4. Implications for policy makers

Welfare generation by the food marketing chain has been shown in the model to be affected by competitiveness of markets and by cost and consumer demand interactions between marketing chains. Although the model’s results reflect the authors’ beliefs about existing commercial behaviour, rather than predict it *per se*, several implications for policy makers emerge.

First, the relative changes in aggregate welfare from the exercise of market power are very much smaller than those experienced by individual stages of a single chain. This is because the exercise of market power has generally been shown to involve the appropriation of surplus by one agent from another, rather than an overall reduction in welfare. Input market power by processors, for example, affects aggregate welfare rather little while greatly affecting farmers’ profits. Moreover, averaging of welfare impacts over just two products in the model has the effect of halving the effect in a single chain: practical policy design involves very large numbers of products so that even extreme impacts may be diluted in the analysis.

Second, the model presents economies of scope technology as a public good (the whole chain benefits in aggregate). However, no firm has the incentive to introduce it, but rather to wait for other chain members to do so. As such, a market failure is identified that appears to be being avoided by the exercise of market power to prevent uncontrolled product volumes upsetting market prices. This may indicate a policy choice: toleration of market power up to certain “critical values” in order to ensure that such technologies are employed where they are socially beneficial.

Where firms’ merger plans are justified by cost savings within the food chain, policy analysts should consider the competitive environment in which such cost savings could be achieved. Policies that require investments that clearly predispose to economies of scope (e.g. procedural change to satisfy food safety, or requirements for the provision of product information) may favour firms that exercise market power, and penalise firms operating in competitive markets.
Third, the model has shown that the benefits of farm-level innovation can be appropriated by other chain participants at the expense of both farmers and consumers. Moreover, this process is more pronounced under certain sets of conditions for interactions between chains, and between products at retail level. Firms that exercise market power apparently face a choice between appropriating other firms’ benefits and sharing on the benefit generated for the entire chain. In the event that innovation at farm level ceases to be profitable, all chain members stand to lose. Given the substantial past, and current, government investment in generating and maintaining innovation at farm level, this development is of concern to policy makers. In particular, such investments may be flowing primarily to processors and retailers, and pressure may be exerted to increase that flow as farmers’ incentives to innovate are eroded.

Fourth, the model suggests relationships between price transmission and the impacts of the exercise of market power: particularly in the context of firms with market power being able to appropriate surplus from such changes as innovation and demand shocks. Price transmission is thus an important indicator of within-chain relationships that may be used as an indicator of imperfect competition.

6.5. **Strengths and weaknesses of the model, and further research**

The model presented in this report features linear supply and demand functions and rudimentary cost functions and structures. There may be limitations to the extent to which these components can be synthesised into multiple-stage and multiple-product behavioural models, and for this reason we circumscribe some of our initial results. In particular, this applies to the discovery of a linkage between incentive for the use of economies of scope technologies and market power. Further work on this model is targeting bounds on responsiveness of the “complex” elasticities than apply between stages. However, the results adhere to some clear principles and so offer inference here.

Extension to more than two products, and more than three stages, is an obvious extension of the model. The complexity of the necessary algebra, and the challenges of inference from the existing model, make this a low priority for further work. The model’s treatment of volumes at each stage of the chain is rudimentary, and might be improved upon by specification of non-unitary conversion factors between stages. This would also enable a richer cost specification to address economies of scope.
The model does not extend to the topic of economies of scale. This is problematic as much food industry development draws contrasts between the impacts of scale (as employed by processors) and scope (as employed by retailers). Economies of scale require special treatment in terms of first and second order conditions for profit maximisation, primarily requiring an exogenous output choice in the model. It is suggested that the current model offers valuable inference by its endogenous output choice, and future developments would seek to maintain this.

Practical applications of the model have been limited to the investigation of innovation, modelled as a simple supply shift. Richer specification of cost functions throughout the chain would enable a more sophisticated approach to innovation, particularly in being able to specify a particular form of innovation, and by allocating costs of innovation throughout the chain as well as to government.
References


Mathematical appendix

*Derivation of elasticities and price relationships*

Define

\[ \frac{1}{\varepsilon_{11}^W} = \frac{\partial P_1^W}{\partial Y_1} \frac{Y_1}{P_1^W}, \quad \frac{1}{\mu_{12}} = \frac{\partial P_2^W}{\partial Y_1} \frac{Y_1}{P_2^W} \text{ and } \frac{1}{\eta_{11}^F} = \frac{\partial P_1^F}{\partial Y_1} \frac{Y_1}{P_1^F} \]

and utilising \( P_1^F = MC_1^F = b_1 + \beta_1 Y_1^F \) such that \( \frac{1}{\eta_{11}^F} = \beta_1 \frac{Y_1}{P_1^F} \)

**Case I (successive input market power)**

\( P_1^W = 2Y_1 Y_2^{-\delta^W} - \delta^W Y_2 Y_1^{-\delta^W} b_1 + \beta_1 Y_1 + \Phi_1^W \beta_1 Y_1 \)

\[ \frac{1}{\eta_{11}^W} = \frac{\partial P_1^W}{\partial Y_1} \frac{Y_1}{P_1^W} = \left[ 2Y_1 Y_2^{-\delta^W} + \delta^W (\delta^W + 1) Y_2^2 Y_1^{-\delta^W} + (\beta_1 + \beta_1 \Phi_1^W) Y_1 \right] \frac{1}{P_1^W} > 0 \]

\( P_2^W = 2Y_2 Y_1^{-\delta^W} - \delta^W Y_1 Y_2^{-\delta^W} b_2 + \beta_2 Y_2 + \Phi_2^W \beta_2 Y_2 \)

\[ \frac{1}{\eta_{21}^W} = \frac{\partial P_2^W}{\partial Y_1} \frac{Y_1}{P_2^W} = \left[ -2\delta^W Y_2 Y_1^{-\delta^W} - 2\delta^W Y_2^2 Y_1^{-\delta^W} \right] \frac{1}{P_2^W} < 0 \]

\[ \frac{1}{\eta_{11}^F} = \frac{\partial P_1^F}{\partial Y_1} \frac{Y_1}{P_1^F} = \beta_1 \frac{Y_1}{P_1^F} > 0 \]
Case II (processors market power)

\[
P_1^W = A_1 - A_{11} Y_1 - A_{12} Y_2 - 2Y_1 Y_2^{1-\delta^R} + \delta^R Y_2^{2-\delta^R} - 1
\]

\[
\frac{1}{\varepsilon_{11}^W} = \frac{\partial P_1^W}{\partial Y_1} \frac{Y_1}{P_1^W} = \left[-A_{11} Y_1 - 2Y_1 Y_2^{1-\delta^R} - \delta^R (\delta^R + 1) Y_2^{2-\delta^R} - 1\right] \frac{1}{P_1^W} < 0
\]

\[
P_2^W = A_2 - A_{21} Y_1 - A_{22} Y_2 - 2Y_2 Y_1^{1-\delta^R} + \delta^R Y_1^{2-\delta^R} - 1
\]

\[
\frac{1}{\varepsilon_{21}^W} = \frac{\partial P_2^W}{\partial Y_1} \frac{Y_1}{P_2^W} = \left[-A_{21} Y_1 + 2Y_2 \delta^R Y_1^{1-\delta^R} + 2\delta^R Y_1^{2-\delta^R} - 1\right] \frac{1}{P_2^W}
\]

\[
\frac{1}{\eta_{11}^F} = \frac{\partial P_1^F}{\partial Y_1} \frac{Y_1}{P_1^F} = \beta_1 \frac{Y_1}{P_1^W} > 0
\]

Case III (retailer market power)

\[
\frac{1}{\varepsilon_{11}^R} = \frac{\partial P_1^R}{\partial Y_1} \frac{Y_1}{P_1^R} = -A_{11} \frac{Y_1}{P_1^R} < 0
\]

\[
\frac{1}{\varepsilon_{21}^R} = \frac{\partial P_2^R}{\partial Y_1} \frac{Y_1}{P_2^R} = -A_{21} \frac{Y_1}{P_2^R} < 0
\]

\[
P_1^W = 2Y_1 Y_2^{1-\delta^W} - \delta^W Y_2^{2-\delta^W} + b_1 + \beta_1 Y_1 Y_2^{2-\delta^W} - 1
\]

\[
\frac{1}{\eta_{11}^W} = \frac{\partial P_2^W}{\partial Y_1} \frac{Y_1}{P_2^W} = \left[\beta_1 Y_1 + 2Y_2 \delta^W + \delta^W (\delta^W + 1) Y_2^{2-\delta^W} - 1\right] \frac{1}{P_2^W} > 0
\]

\[
P_2^W = 2Y_2 Y_1^{1-\delta^W} - \delta^W Y_1^{2-\delta^W} + b_2 + \beta_2 Y_2
\]

\[
\frac{1}{\eta_{21}^W} = \frac{\partial P_2^W}{\partial Y_1} \frac{Y_1}{P_2^W} = \left[-2\delta^W Y_2 Y_1^{1-\delta^W} - 2\delta^W Y_1^{2-\delta^W} - 1\right] \frac{1}{P_2^W} < 0
\]
Case IV (successive output market power)

\[
\frac{1}{\varepsilon_{11}^R} = \frac{\partial P_1^W}{\partial Y_1} \frac{Y_1}{P_1^W} = -A_{11} \frac{Y_1}{P_1^R} < 0
\]

\[
\frac{1}{\varepsilon_{21}^R} = \frac{\partial P_2^R}{\partial Y_1} \frac{Y_1}{P_2^R} = -A_{21} \frac{Y_1}{P_2^R} < 0
\]

\[
P_1^W = A_1 - A_{11} Y_1 - A_{12} Y_2 - \Theta_1 A_{11} Y_1 - \Theta_1 A_{21} Y_2 - 2Y_1 Y_2^{-\delta^R} + \delta_1^R Y_2^2 Y_1^{-\delta^R - 1}
\]

\[
\frac{1}{\varepsilon_{11}^W} = \frac{\partial P_1^W}{\partial Y_1} \frac{Y_1}{P_1^W} = \left[ -A_{11} Y_1 - \Theta_1 A_{11} Y_1 - 2Y_1 Y_2^{-\delta^R} - \delta_1^R \left( \delta_1^R + 1 \right) Y_2^2 Y_1^{-\delta^R - 1} \right] \frac{1}{P_1^W} < 0
\]

\[
P_2^W = A_2 - A_{21} Y_1 - A_{22} Y_2 - \Theta_2 A_{22} Y_2 - \Theta_2 A_{12} Y_1 - 2Y_2 Y_1^{-\delta^W} + \delta_2^R Y_1^2 Y_2^{-\delta^R - 1}
\]

\[
\frac{1}{\varepsilon_{21}^W} = \frac{\partial P_2^W}{\partial Y_1} \frac{Y_1}{P_2^W} = \left[ -A_{21} Y_1 - \Theta_2 A_{12} Y_1 + 2Y_2 Y_1^{-\delta^R} \delta_2^R + 2\delta_2^R Y_1^2 Y_2^{-\delta^R - 1} \right] \frac{1}{P_2^W}
\]
# Working Papers

**Institute of Food and Resource Economics**

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<tr>
<th>Date</th>
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<td>Innovation in a multiple-stage, multiple-product food marketing chain</td>
<td>Derek Baker, Tove Christensen</td>
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<td>Modeling Agricultural Domestic Support in China: recent policy reversals and two future scenarios</td>
<td>Wusheng Yu, Hans G. Jensen</td>
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