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Evaluating the Potential Returns to Investment in RD&E in the Southern Australian Grains Industry

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Abstract

Over recent decades, the Australian grains industry has faced various challenges arising from changing climate, increases in extreme weather events and declining public research, development and extension (RD&E). At the same time, there has been growing competition in Australia's main grain export markets. To increase the annual rate of productivity growth and maintain international competitiveness, more and better-aimed investments in agricultural RD&E are required. Equilibrium Displacement Models (EDMs) provide a framework for assessing the potential economic returns to investments in agricultural RD&E and the distribution of these returns along the industry supply chain.

In this paper, an EDM for the southern Australian grains industry, encompassing South Australia, Victoria and Tasmania, is developed as a companion to the previously developed EDM of the WA grains industry. Using the EDM, three hypothetical RD&E investment scenarios are examined: a reduction in the cost of farm production variable inputs resulting from new farm technologies or improvements in cropping processes and practices; a cost reduction in stockfeed manufacturing resulting from new technologies and improved industrial techniques; and an increase in the willingness of overseas consumers to pay for wheat due to quality improvements or promotion. The results show that, directing RD&E towards a market segment of the supply chain with high gross revenue generates greater returns to the industry as a whole. As such, RD&E investment aimed at either farm production or bulk wheat export—segments of the supply chain which account for substantial gross value at farm gate and port—can yield high returns. Additionally, producers gain a greater share of benefits when productivity-enhancing research is directed towards on-farm rather than off-farm processes. Furthermore, producers can accrue large shares of the total benefits arising from research that enhances the quality of bulk grain exports because of the high price elasticity of demand for export grains.

Keywords: grains industry, southern grains region, equilibrium displacement models, RD&E

Introduction

The Australian grains industry has grown markedly over the past 40 years, supported by changing markets and structural adjustments to the industry such as increased farm size, a greater intensity of cropping, increased use of large farm machinery, changes in tillage methods and the introduction of herbicides (Kingwell *et al*., 2019). In addition, consolidation of bulk handling companies and statutory marketing boards occurred, along with gradual deregulation of the statutory marketing arrangements, culminating in the removal of the single desk marketing arrangements for export wheat in 2008 (Productivity Commission, 2010).

Challenges have emerged however. The global grain market has become increasingly competitive with emerging competitors from the Black Sea Region and Argentina now posing a challenge for Australia's key grain export markets in Asia (Kingwell, 2019). Also, since the 1990s, growth in total factor productivity growth along with profitability has slowed, attributed to factors such as the adverse impacts of a warming climate and more frequent extreme weather events, a decline in expenditure on agricultural RD&E, a re-direction of research priorities away from enhancing farm productivity, and a slower adoption of new technologies (Hockman *et al.*, 2017; Primary Industries Standing Committee, 2011). Some recovery in broadacre farm performance has occurred since the late 2000s due to more favourable seasons and prices for both grain and livestock and the advent of new higher-yielding crop varieties (Boult & Chancellor, 2020; Trainor *et al*., 2018).

The adoption of the outputs of RD&E are key to enhancing productivity and maintaining and increasing profitability in the industry (GRDC, 2020a). For instance, Sheng *et al*. (2011) found that between 1952–53 and 2006–07, growth in public RD&E stocks of knowledge accounted for more than half the annual increase in total factor productivity in the Australian broadacre agriculture sector. The Grains Industry National Research, Development and Extension Strategy recognises that to maintain international competitiveness, annual average growth in total factor productivity of more than 2.5 per cent will be needed by 2025 (Research and Innovation Committee, 2017). Underpinning this objective is the need for more and better-aimed investments in RD&E. However, allocating funding to RD&E poses challenges and trade-offs. Decisions must be made about how much funding to allocate to competing research projects, with different investment decisions having different potential returns and distributional impacts for producers, processors and consumers.

Equilibrium Displacement Models (EDMs) can be used to evaluate the returns to RD&E and the distribution of benefits for different participants along the value chain. An understanding of the returns associated with different RD&E investment scenarios is useful for funding agencies making investment decisions and setting investment priorities. Similarly, both producers who pay levies and taxpayers have a vested interest in grower's and public funds for research being used in ways that maximise net benefits to their industry and the community.

In this paper, an EDM is constructed and tested for the Grains Research and Development Corporation's (GRDC) 'southern' region grains industry, comprising South Australia, Victoria and Tasmania. The paper is a companion piece to the report of the EDM of the Western Australian (WA) grains industry presented in Li *et al.* (2019). This paper proceeds as follows: Section 2 provides an overview of the Australian and southern region grains industries, describing the major commodity types, challenges, and the importance of targeted RD&E. Section 3 briefly outlines the modelling approach. Section 4 presents the EDM for the southern region grains industry, detailing its structure, input data and key conceptual considerations. Section 5 provides the simulation results for three hypothetical investment scenarios. Section 6 discusses some caveats and suggestions for further research. A summary and conclusion follows in Section 7.

Industry and Strategic Overview

Australia

The grains industry is a significant component of the agricultural sector in Australia. In 2018-19, the gross value of production for the three main categories of grains – cereal grains, oilseeds and pulses totalled $12.5 billion, representing around 21 per cent of the total gross value of farm production (ABARES, 2020a). The major winter cereals in Australia are wheat, barley and canola. A summary of average annual winter crop area and production from 2014-15 to 2018-19 is provided in Table 1.

Most grain crops have multiple end uses domestically and overseas. Domestic grain production underpins the food processing industry, including wheat products such as breads, noodles and pastas. Other grains such as barley are used for malting and brewing. Coarse grains such as feed barley, maize and sorghum are used mainly as animal feed for Australia's grain-fed beef, dairy, pork and poultry industries. Some cereals and pulses are used as supplementary feeds for farm animals such as sheep and cattle. In addition to domestic use, a large volume of grain production is exported overseas. An average of $11 billion worth of grain exports was recorded over the five-year period from 2014-15 to 2018-19 (ABARES, 2020a).

Table 1. Australian average annual winter crop area and production, 2014-15 to 2018-19

	Area ('000 ha)	Production (kt)
Wheat	11,436	23,275
Barley	4,316	9,843
Canola	2,592	3,378
Chickpeas	708	927
Faba beans	233	343
Field peas	245	277
Lentils	302	401
Lupins	553	749
Oats	903	1,425
Triticale	65	113

Source: ABARES (2020b)

Southern grains region

Australia's southern grains region encompasses South Australia, Victoria and Tasmania shown in the shaded region in Figure 1. Most grain in this region is grown in South Australia and Victoria. This grain growing region is characterised by relatively infertile soils, a temperate climate and yields that depend on reliable spring rainfall. In 2018-19, the gross value of grain production in the southern grains region totalled $3.87 billion, with $1.97 billion attributed to South Australia and $1.89 billion attributed to Victoria (Australian Bureau of Statistics, 2020).

A summary of average annual winter crop production in the southern grains region over 2014-15 to 2018-19 in provided in Table 2. The region accounts for around one-third of annual wheat, barley and canola production in Australia, most of which is exported. Highly variable weather and rainfall in recent years has caused variability in grain production, fluctuating from a record-breaking harvest in 2016-17 to the extremely low production year of 2018-19 caused by drought.

A historical snapshot of grain exports in the southern region from 2011-12 to 2015-16 is shown in Table 3. Average annual exports as a proportion of total production was around 90 per cent for wheat and canola, and 70 per cent for barley. Grain is moved interstate to meet supply shortfalls in other states. Usually some grain is brought into South Australia and Victoria to meet demand for domestic use. The northern grain growing region in NSW is the usual source. An estimate of domestic grain inflows to the southern region over the 2011-12 to 2015-16 period is provided in Table 4.

Figure 1. Southern Grains Region

Source: GRDC (2020b)

Table 2. Southern grains region average annual winter crop area and production, 2014-15 to 2018-19

	Area ('000 ha)	Production (kt)
Wheat	3,394	7,359
Barley	1,763	3,852
Canola	627	887
Chickpeas	35	60
Faba beans	180	248
Field peas	164	179
Lentils	293	393
Lupins	104	109
Oats	212	369
Triticale	28	41

Source: ABARES (2020b)

Table 3. Southern grains region exports

	2011-12	2012-13	2013-14	2014-15	2015–16
	kt	kt	Kt	kt	kt
Wheat	9,958	6,729	7,495	6,119	5,433
Barley	2,990	2,475	2,936	2,304	1,963
Canola	931	1,536	1,070	710	450

Source: Australian Crop Forecasters, Supply and Demand Report

Several major grain handling companies operate in the southern region, the larger of which include Viterra, Emerald and GrainCorp. Viterra is the main handler of grain in South Australia operating 89 receival sites in the State, comprising 80 per cent of all up-country grain storage in the State

Table 4. Southern region grain inflows from other cropping regions

	2011-12	2012-13	2013-14	2014-15	2015–16
	kt	kt	Kt	kt	kt
Wheat	1,350	1,500	1,050	1,290	1,150
Barley	450	520	50	80	215
Canola	150	430	160	150	150

Source: Australian Crop Forecasters, Supply and Demand Report

(Stretch *et al*., 2014). Viterra owns all six bulk grain ports in South Australia, although some new entrants to export grain port services are emerging. In Victoria, there is greater competition in grain handling, with several key bulk handlers sharing the market. The largest of these are Emerald and GrainCorp.

Policy environment and industry challenges

The Australian grains industry has grown markedly over the past 40 years as a result of changing markets and an annual growth in total factor productivity of 1.5 per cent (Boult & Chancellor, 2020). Increases in agricultural productivity lead to either more output produced with the same level of measured inputs, or the same amount of output being produced with a smaller quantity of measured inputs.

Policy reforms to the industry have contributed to the historical growth in productivity. This includes gradual deregulation of the statutory marketing arrangements, culminating in the removal of the single desk marketing arrangements for export wheat in 2008 along with privatisation of publicly owned grain handling authorities (Productivity Commission, 2010). These reforms facilitated structural adjustments in the industry including the consolidation of private bulk handling, amalgamation of farms with the associated reallocation of resources from less productive to more productive farms, improvements in risk management and a greater intensity of cropping (Kingwell, 2017; Sheng *et al*., 2015). Advances in knowledge and technology played a significant role in improving productivity such as larger farm machinery, changes in tillage methods and the introduction of herbicides (Kingwell *et al*., 2019).

Despite these gains, since the 1990s, the rate of increase in average total factor productivity has declined (Hockman *et al.*, 2017; Primary Industries Standing Committee, 2011). The poor productivity performance of the past 20 years is likely related to a marked reduction in growing seasonal rainfall in grain growing districts, as well as research-related factors such as declining rates of annual increase in publicly-funded RD&E or changes in research priorities. In addition, the global grain market has become increasing competitive with emerging competitors from the Black Sea Region and Argentina now posing a challenge for Australia's key export markets in Asia (Kingwell, 2019).

Productivity and RD&E

Productivity is measured by the quantity of outputs produced for a given quantity of inputs, with higher long term growth in productivity enabling profit and competitiveness of many growers to be maintained in the face of the long-term decline in growers' terms of trade, where the prices received for farm products have declined relative to input prices (Primary Industries Standing Committee, 2011). Key to improvements in total factor productivity is investments in RD&E which lead to new knowledge and technologies (Khan *et al*., 2017). Research, development and extension can be conducted either on-farm or off-farm. Various benefits on farms from rural RD&E include:

- improved farm management;
- new plant varieties;
- improved crop rotations;
- better disease, weed and pest control; and
- advances in cropping tools and technologies.

The benefits can in turn, deliver increases in farm productivity. The Research and Innovation Committee (2017) claimed that hitherto, around one-third can be attributed to genetics (varieties) and two-thirds to farm management and agronomy systems (practices).

In addition, knowledge arising from research can lead to off-farm benefits along the supply chain such as:

- enhanced pathways for grain storage and transport logistics;
- innovations to freight, storage and grain handling technology and systems; and
- improved market access through product integrity and traceability.

Strategic approach to RD&E investments

Investments in RD&E in the Australian grains industry is predominantly carried out by the GRDC. The GRDC sources its funding from both grain growers and Commonwealth Government. Other funding providers for grains RD&E include state and territory governments and universities along with private research and development companies. As such, funding bodies and producers alike have a vested interest in the efficient allocation of funds to maximise their returns.

In 2019-20, GRDC's income totalled $173.2 million, consisting of $95.8 million in grower levy contributions and $59.4 million in Commonwealth Government contributions, along with $18.1 million from other revenue sources (GRDC, 2020c). The GRDC is currently pursuing investment objectives outlined in the *GRDC Research, Development and Extension Plan 2018-23* (GRDC, 2020d), which aims for the industry to achieve a minimum 6 per cent rate of return by 2023 through its focus on improving yield and prices, optimising and reducing input and post-farm gate costs and managing risk. These key investment objectives aim to address many of the industry challenges previously outlined.

However, allocating funding to RD&E investment priorities poses challenges and trade-offs under limited funding, with different investment decisions having different payoffs and distributional impacts. The GRDC is also exposed to budget volatility, as levies collected from grain growers can fluctuate each year depending on grain growing conditions. As noted in the Grains Industry National RD&E Strategy (2017, p. 30), 'the modest size of Australia's RD&E budget in the global context dictates that investment decisions must be strategic to achieve the best effect in industry innovation.' Hence, this necessitates the need for better targeted investments in RD&E.

To evaluate the merits of a particular research investment, it is necessary to have an understanding of the size of its potential benefits, as well as the welfare implications for various industry groups along the supply chain. An EDM framework can help answer these questions.

Modelling Approach

Equilibrium Displacement Models can be used to estimate the potential net benefits of innovations and/or policies for an industry. The comparative static method of EDMs involves representing the multi-stage market structure of an industry by a set of supply and demand equations with general functional forms. An initial equilibrium for the industry is calibrated using base data for prices and quantities that represent a typical or average of a run of years. As such, EDMs do not require extensive time series data. Elasticities in the markets involved are specified which describe the responsiveness of quantity variables to price changes at each market level. The impacts of changes to supply or demand are represented by exogenous shocks or 'displacements' in demand or supply from their initial equilibrium values, with new equilibrium values traced out using comparative statics. The overall economic impacts along with the distributional effects across the industry are estimated.

Equilibrium displacement models have previously been developed to evaluate RD&E benefits for a number of agricultural industries, including grains (Li *et al.*, 2019), beef (Zhao *et al.*, 2000), sheep and wool (Mounter *et al.*, 2008), pig meat (Mounter *et al.*, 2004), dairy (Liu et al., 2012; Ludemann et al., 2016) and wine (Zhao *et al.*, 2002).

In this present study, an EDM is developed to estimate the size and distribution of net benefits to the southern grains region of a change in productivity resulting from investments in RD&E in the southern region grains industry.

Equilibrium Displacement Model of the Southern Region Grains Industry

The EDM constructed in this paper provides a stylised representation of the southern region grains industry. It serves as a companion to the EDM of the western grains region constructed and tested by Li *et al.* (2019). Here, the industry is represented by nine industry groups—farm production, up-country storage for wheat, up-country storage for barley, up-country storage for canola, up-country storage for peas, flour milling, stockfeed manufacturing, malt manufacturing, and canola processing, along with four grain types—wheat, barley, canola and peas.

Conceptualisation of crop rotations

Grain cropping is typically a sequential system of activities (Malcolm et al., 2005; Malcolm and Armstrong, 2016). Crops are grown in sequences on cropland over several years because there are complementary effects on yields through disease and pest management, soil fertility, and weed control. The need to model rotations of crops and with a time dimension adds complexity in the modelling process. This becomes especially problematic in the context of EDMs as they are a comparative static framework of economic analysis, meaning that only two different equilibrium states are compared and analysed. The sequential rotation of crops in a field over several years cannot be simply captured using such a framework. However, a steady-state representation of the crop system can be generated by assuming that each phase of a crop sequence is present during each year (see Malcolm and Armstrong, 2016, pp. 1-2). Instead of examining the crop system across time, it is represented at a particular time – one year, as shown in Figure 2.

In this example, the crop rotation consists of four grain types: wheat, barley, canola and a pulse (grain legume) serving as a break crop. The cropland is divided into four cropping areas with each grain type being present in one of the cropping areas at any point in time. Moving across time, each crop moves through the sequence across areas. This same conceptualisation of the treatment of rotations to form a steady state representation is used also in mathematical programming models of farming systems. A well-known Australian example is the MIDAS (Model of an Integrated Dryland Agricultural System) model of typical broadacre Australian farming (Kingwell & Pannell, 1987; Kingwell, 1996; O'Connell *et al*., 2006; Thamo *et al*., 2013).

Figure 2. Addressing crop rotations in a comparative static framework

Across time

At a point in time

	Year 1	Year 2	Year 3	Year 4
Area 1	Wheat	Barley	Canola	Pulse
Area 2	Barley	Canola	Pulse	Wheat
Area 3	Canola	Pulse	Wheat	Barley
Area 4	Pulse	Wheat	Barley	Canola

The wide variety of crops grown in broadacre farming (see GRDC, 2020e; GRDC, 2020f) makes it impractical to incorporate the entire set of crops grown in a model. Only the major crops are modelled in the EDM. A practical and profitable cropping sequence for growers is wheat, barley and canola with a pulse as a break crop. For the southern cropping region, a commonly grown pulse is peas. In this study it assumed that the cropping sequence of cereals, oilseed and grain legume, viz. wheat/barley/canola/peas, is representative of cropping sequences across the entire regional industry for the southern cropping region.

Model structure

In Figure 3 the schematic of the industry for the EDM is shown. Each rectangle represents a multi-output production function. Each arrow represents the market for a product, with the arrowed end being the demand for a product, and the non-arrowed end being the supply of the product. Each oval represents the supply and demand schedule of a product where an exogenous shift may occur.

There are nine industry groups whose multi-output production functions and decision-making problems can be specified completely within the model. The model also captures grain inflows from the other cropping regions (usually the northern region).

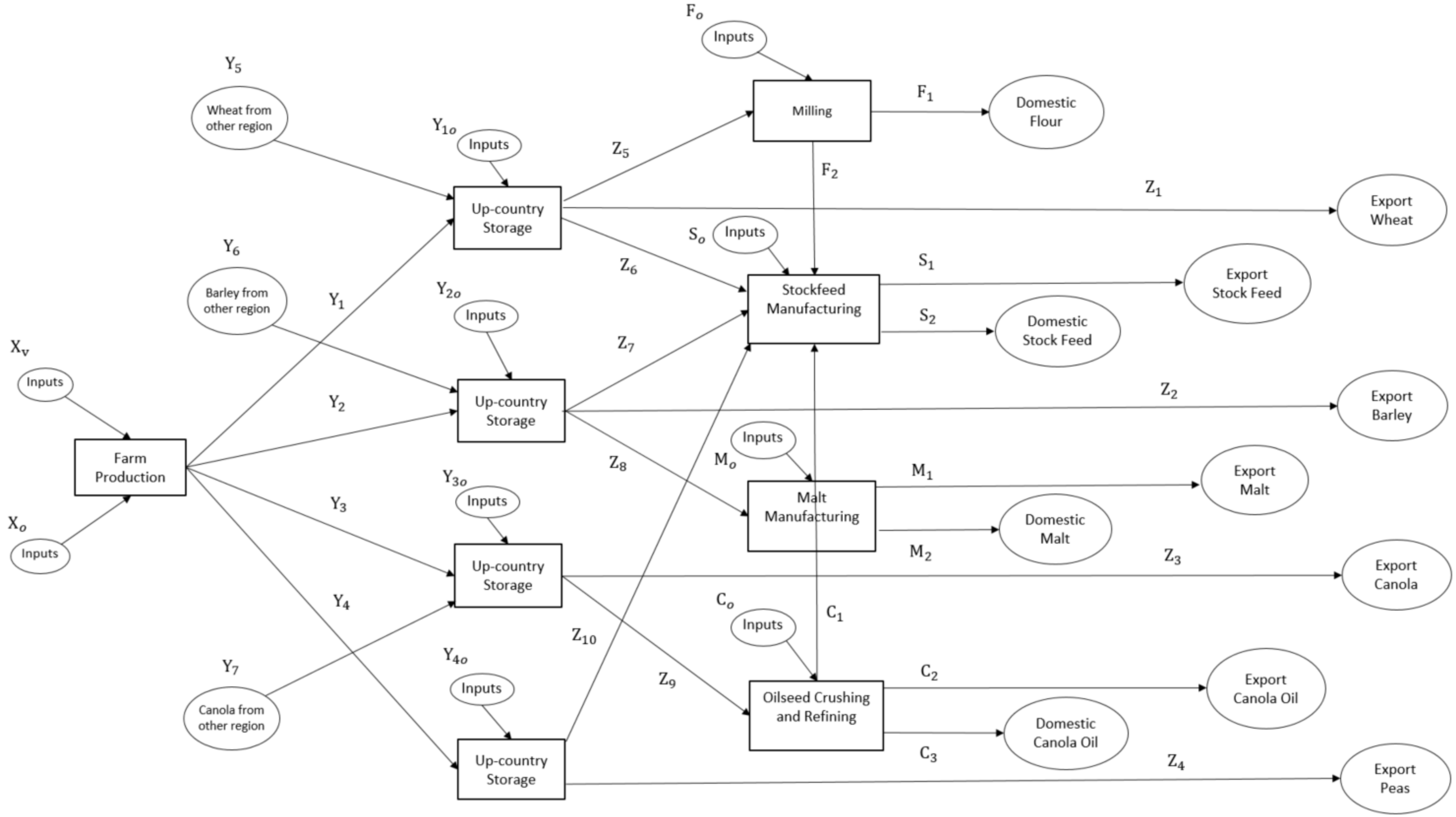
The notation used to represent the various inputs and outputs is provided in Appendix A. The formal details of the justification and specification of the model and the structural model in algebraic form are presented in Appendix D.

The model in displacement form

The equations for the model follow the specifications of Zhao *et al.* (2000) and Mounter *et al.* (2008). All the production functions are deemed to exhibit constant returns to scale with multi-output production functions separable in inputs and outputs. The objective of profit maximisation is an implicit behavioural assumption of each industry sector within the model. Perfect competition over the medium term is assumed along each sector of the industry's supply chain. This means that under the assumptions of competition and constant returns to scale, total costs must equal total revenue for each sector (zero economic profits).

The analytical system given by equations (28) to (111) in Appendix D defines an equilibrium status in all the markets in the model. These equations represent the structural equilibrium model of the southern region grains industry in general functional form. To examine the impacts of exogenous

Figure 3. Model structure of the southern region grains industry



shocks in the industry, the system of equations needs to be converted to a 'displacement form'. This can be done by totally differentiating the system of equations at the initial equilibrium points and converting them to percentage change form. This model in displacement form is provided in Appendix E and consists of 90 equations. A small percentage change in variable (.) is denoted as (.)=Δ(.)/(.).

Exogenous supply shock variables, denoted by Y(.), represent the impacts brought about by new technology, and exogenous demand shock variables, denoted by N(.), represent the impacts of market research or promotion. This method allows for approximations of the changes in prices and quantities caused by a shock without any knowledge of the specific functional forms of the demand and supply curves, so long as the exogenous shifts are small and parallel.

To satisfy the integrability conditions, homogeneity and symmetry restrictions have been imposed on all the input demand and output supply functions in the EDM, whereas concavity and convexity conditions are satisfied when setting the parameter values (see Zhao *et al.* (2000) for a detailed discussion on integrability conditions).

Input data

The objective of using an EDM is to estimate changes in all prices and quantities to infer welfare implications of the exogenous shifts. To achieve this data are required on: (i) initial equilibrium price and quantity values for all industry groups of the model; (ii) market elasticities; and (iii) values specified for the exogenous shift variables for all simulated scenarios. The notation used in representing all variables and parameters is provided in Appendix A.

Price and quantity

Information and data on the production, distribution and use of Australian grains and grain products for this study is obtained from various sources: Australian Crop Forecasters, ABARES, AEGIC, Rural Bank, JCS Solutions, IBISWorld, industry experts and subjective judgements. Base equilibrium values for crop production were specified as the mean prices and quantities reported by the Australian Crop Forecasters and ABARES over the five year period 2011-12 to 2015-16, accounting for a medium run length of industry activity. These average base equilibrium values are summarised in Appendix B.

Atypical production years such as the record high 2016-17 season and low 2018-19 and 2019-20 seasons were excluded in order to produce a smooth calibration. In addition, this time period will not be affected by the structural effects of the regulated single-desk wheat marketing arrangements that operated prior to 2008.

Market parameters

An EDM uses estimates of price elasticities of supply and demand for each market in the industry. These estimates reflect the nature of the demand, supply, input substitution and product transformation processes in each market. Obtaining empirical estimates of price elasticities of supply and demand of different markets is the key to a reliable EDM. Results are sensitive to different values of price elasticities and lead to different conclusions.

Historically robust estimates of many elasticities have been difficult to obtain with many studies having relied on expert opinion and subjective judgement. Estimates of agricultural elasticities vary according to geographic coverage, length of run, sample periods, estimation method, functional form, and explanatory variables used in the estimation process (Griffith & I'Anson, 2001).

Values of the elasticity values used in this study were based on a combination existing econometric estimations and subjective judgement. Appendix C lists these elasticity values for the base conditions. A detailed review and justification of these elasticity values is provided in Li *et al.* (2019).

Exogenous shifts

There are 21 exogenous variables consisting of 10 supply shift variables and 11 demand shift variables. The supply shifts represent the effects of research-induced reductions in the cost of production in industry sectors and the demand shifts are the result of promotion or quality improvements in different markets.

The impacts of three hypothetical RD&E investment scenarios are investigated. For each scenario, a different market segment in the supply chain is targetted, with Scenario 1 representing a shift in supply in upstream production, Scenario 2 focusing on a shift in supply in intermediate processing, and Scenario 3 being a shift in demand of end consumers. Scenarios 1 and 2 relate to productivity-enhancing research represented by a supply side shock, whereas Scenario 3 relates to quality-enhancing research represented by a demand side shock.

Scenario 1 involves new technologies or practices adopted from RD&E that either reduce the variable costs of farm production or increase the productivity of these inputs. This scenario relates to the GRDC's RD&E investment priorities of optimising input costs and maintaining and improving price (see GRDC, 2020d). This is modelled as a 1 per cent downward shift of the supply curve of these variable inputs to the farm sector, corresponding to $\mathrm{t}_{\mathrm{Xv}} = -0.01$. Variable inputs consist of raw materials such as seed, fertiliser, fuel, water, and chemicals, along with other materials and services. As noted in the base equilibrium input values (Appendix B), variable costs of farm production in the southern region grains industry comprise 67 per cent of total farm production costs.

Scenario 2 concerns new processing technologies or practices adopted from RD&E that either reduce the costs of stockfeed manufacturing or increase its productivity. This scenario relates to the GRDC's RD&E investment priority of reducing post-farm-gate costs (see GRDC, 2020d). This is modelled as a 1 per cent downward shift of the supply curve of non-grain inputs to the stockfeed manufacturing market ($\mathrm{t}_{\mathrm{So}} = -0.01$).

In Scenario 3 the effects of a 1 per cent increase in overseas consumers' willingness to pay for wheat is simulated. This can arise through an improvement in the quality of wheat through RD&E or through investments in advertising, education and promotion in overseas markets. This is connected to the GRDC's RD&E investment priority of improving trade and market access for Australian grain into export markets (see GRDC, 2020d). This is represented as an upward shift of the demand curve of wheat sold in the export market ($\mathrm{n}_{\mathrm{Z1}} = 0.01$).

The results for these three investment scenarios are presented and discussed in the next section.

Results

A summary of the simulation results from the base model calibrated using data specified in Section 4 is provided in this section. The final displacements in market prices and quantities are reported as percentage changes for each investment scenario (Table 5). In these scenarios, the shifts considered are small parallel shifts, ensuring that approximation errors are small and that estimates of price and quantity changes are accurate.

The changes in prices and quantities are used to estimate the distribution of economic benefits for the different sectors within the industry. These changes in welfare for each investment scenario are summarised in Table 6.

Table 5. Percentage changes in prices and quantities (%)

	Scenario 1 ($t_{Xv} = -1\%$)	Scenario 2 ($t_{So} = -1\%$)	Scenario 3 ($n_{Z1} = 1\%$)
Quantities:			
eX_v	0.66	0.04	0.60
eX_o	0.53	0.04	0.56
eY_1	0.62	0.04	1.14
eY_2	0.54	0.05	-0.13
eY_3	0.72	0.01	-0.17
eY_4	0.47	0.07	-0.12
eY_{1o}	0.48	0.04	1.05
eY_{2o}	0.45	0.05	-0.11
eY_{3o}	0.56	0.01	-0.13
eY_{4o}	0.36	0.06	-0.10
eY_5	0.02	0.02	0.46
eY_6	0.00	0.02	0.00
eY_7	0.04	0.01	-0.01
eZ_1	0.59	0.02	1.24
eZ_2	0.63	0.00	-0.15
eZ_3	0.73	-0.01	-0.17
eZ_4	0.70	-0.04	-0.16
eZ_5	0.09	0.03	-0.06
eZ_6	0.32	0.13	0.41
eZ_7	0.17	0.20	-0.08
eZ_8	0.24	0.01	-0.06
eZ_9	0.25	0.06	-0.07
eZ_{10}	0.15	0.21	-0.07
eF_o	0.06	0.03	-0.03
eF_1	0.07	0.03	-0.05
eF_2	0.08	0.03	-0.05
eS_o	0.17	0.24	0.11
eS_1	0.41	0.36	0.26
eS_2	0.12	0.11	0.08
eM_o	0.19	0.01	-0.05
eM_1	0.25	0.01	-0.06
eM_2	0.08	0.00	-0.02
eC_o	0.20	0.06	-0.06
eC_1	0.24	0.06	-0.07
eC_2	0.37	0.09	-0.10
eC_3	0.12	0.03	-0.03

Prices:			
ew_v	-0.78	0.01	0.20
ew_o	0.53	0.04	0.56
ev_1	-0.34	0.02	0.51
ev_2	-0.37	0.02	0.08
ev_3	-0.30	0.01	0.07
ev_4	-0.39	0.03	0.08
ev_{1o}	0.19	0.02	0.42
ev_{2o}	0.18	0.02	-0.05
ev_{3o}	0.23	0.00	-0.05
ev_{4o}	0.72	0.13	-0.19
ev_5	0.03	0.04	0.92
ev_6	0.00	0.04	-0.01
ev_7	0.08	0.01	-0.02
eu_1	-0.12	0.00	0.75
eu_2	-0.13	0.00	0.03
eu_3	-0.15	0.00	0.03
eu_4	-0.14	0.01	0.03
eu_5	-0.30	0.00	0.27
eu_6	-0.59	0.21	-0.72
eu_7	-0.36	0.11	0.06
eu_8	-0.31	-0.01	0.08
eu_9	-0.31	0.03	0.07
eu_{10}	-0.32	0.09	0.06
eg_o	0.04	0.02	-0.02
eg_1	-0.15	-0.06	0.10
eg_2	0.02	0.53	0.30
et_o	0.17	-0.76	0.11
et_1	-0.10	-0.09	-0.07
et_2	-0.24	-0.22	-0.16
en_o	0.19	0.01	-0.05
en_1	-0.06	0.00	0.02
en_2	-0.15	-0.01	0.04
ed_o	0.20	0.06	-0.06
ed_1	-0.46	0.33	0.05
ed_2	-0.09	-0.02	0.03
ed_3	-0.24	-0.06	0.07

Table 6. Annual economic surplus changes ($ million) and percentage shares of total surplus changes (%) to various industry groups

	Scenario 1 ($t_{Xv} = -1\%$)		Scenario 2 ($t_{So} = -1\%$)		Scenario 3 ($n_{Z1} = 1\%$)	
	$m	%	$m	%	$m	%
ΔPS_{X0}	4.96	27.0%	0.33	8.6%	5.28	32.4%
ΔPS_{Xv}	4.06	22.1%	0.23	6.0%	3.68	22.6%
Farm subtotal	9.02	49.2%	0.56	14.6%	8.96	55.0%
ΔPS_{Y1o} Bulk Storage for wheat	0.90	4.9%	0.07	1.9%	1.98	12.2%
ΔPS_{Y2o} Bulk Storage for barley	0.46	2.5%	0.05	1.2%	-0.12	-0.7%
ΔPS_{Y3o} Bulk Storage for canola	0.16	0.9%	0.00	0.1%	-0.04	-0.2%
ΔPS_{Y4o} Bulk Storage for peas	0.08	0.5%	0.01	0.4%	-0.02	-0.1%
Bulk Storage subtotal	1.60	8.7%	0.14	3.5%	1.81	11.1%
ΔPS_{Fo} Flour Milling	0.07	0.4%	0.03	0.9%	-0.04	-0.3%
ΔPS_{So} Stockfeed manufacturing	0.70	3.8%	0.98	25.3%	0.44	2.7%
ΔPS_{Mo} Malt Manufacturing	0.18	1.0%	0.01	0.2%	-0.04	-0.3%
ΔPS_{Co} Oilseed Processing and Refining	0.06	0.3%	0.02	0.5%	-0.02	-0.1%
Total Producer Surplus:	11.63	63.4%	1.74	45.0%	11.11	68.2%
Overseas Consumers:						
ΔCS_{Z1} Wheat	2.21	12.0%	0.09	2.3%	4.68	28.7%

ΔCS_{Z2} Barley	0.79	4.3%	0.00	0.0%	-0.18	-1.1%
ΔCS_{Z3} Canola	0.72	3.9%	-0.01	-0.3%	-0.16	-1.0%
ΔCS_{Z4} Peas	0.06	0.3%	0.00	-0.1%	-0.01	-0.1%
ΔCS_{S1} Stockfeed	0.32	1.8%	0.28	7.4%	0.21	1.3%
ΔCS_{M1} Malt	0.10	0.6%	0.00	0.1%	-0.03	-0.2%
ΔCS_{C2} Canola Oil	0.07	0.4%	0.02	0.5%	-0.02	-0.1%
Overseas Consumers subtotal	4.28	23.3%	0.38	9.8%	4.48	27.5%
Domestic Consumers:						
ΔCS_{F1} Domestic Flour	0.47	2.6%	0.18	4.8%	-0.32	-1.9%
ΔCS_{S2} Stockfeed Domestic	1.70	9.3%	1.51	39.0%	1.09	6.7%
ΔCS_{M2} Malt Domestic	0.06	0.3%	0.00	0.1%	-0.01	-0.1%
ΔCS_{C3} Canola Oil Domestic	0.21	1.1%	0.05	1.4%	-0.06	-0.4%
Domestic Consumers Subtotal	2.45	13.3%	1.75	45.2%	0.70	4.3%
Total Consumer Surplus	**6.72**	**36.6%**	**2.13**	**55.0%**	**5.17**	**31.8%**
Total Economic Surplus	**18.36**	**100.0%**	**3.87**	**100.0%**	**16.28**	**100.0%**

Scenario 1: New technology in farm production

This downward shift in supply for variable farm production inputs (X_v) results in higher quantities used and lower prices of these inputs. The reduction in costs of these inputs causes an increase in the supply of wheat (Y_1), barley (Y_2), canola (Y_3) and peas (Y_4) shifting the supply curves of these farm outputs downwards, resulting in increased quantities and reduced prices of these outputs.

Due to the reduced cost in grain production, the supply of outputs in all downstream sectors $(Z_1, Z_2, Z_3, Z_4, Z_5, Z_6, Z_7, Z_8, Z_9, Z_{10}, F_1, F_2, S_1, S_2, M_1, M_2, C_1, C_2, C_3)$ also increases (downwards shift in supply curves), increasing their quantities and decreasing their prices.

The reduction in end market prices for all raw grains and processed grain products results in an increase in consumption in both the domestic and overseas markets for these products. This causes the demand curves for grain outputs from farm production going into up-country storage (Y_1, Y_2, Y_3, Y_4), as well as grain outputs from the storage market going into the secondary processing markets $(Z_5, Z_6, Z_7, Z_8, Z_9, Z_{10})$ to shift upwards to the right. The demand curves for millmix (F_2) and canola meal (C_1) going into stockfeed manufacturing also shift for these reasons. In additional, second round shifts in input demand and output supply also take effect due to substitution effects.

The supply curves of other inputs in all markets $(X_o, Y_{1o}, Y_{2o}, Y_{3o}, Y_{4o}, F_o, S_o, M_o, C_o)$ remain stationary, as they are exogenous inputs to the model. Their demand curves have all shifted upwards because of increases in consumption of grain and grain products.

The supply curves of wheat (Y_5), barley (Y_6) and canola (Y_7) from other regions also remain fixed as they are exogenous inputs to the model. Their demand curves experience marginal upward shifts due to increases in final consumption of grain and grain products.

These displacements cause the total surplus gain for the industry to be an estimated $18.36 million per year. All industry groups experience gains in welfare. The farm production segment is the main beneficiary of the technology shock with a producer surplus of $9.2 million, translating to 49.2 per cent of the total surplus gain. The bulk storage and handling market receives $1.60 million or 8.7 per cent of the total benefits. The prices for export grain and grain products are largely unaffected by the technological shock because of their high export demand elasticities, but export quantities increase. The total benefit accruing to all overseas consumers is $4.28 million or 23.3 per cent of the total benefits. Although not reported, a small amount of benefits is captured by other regions due to an increase in grain flows from these regions.

Compared to the results for the western region presented in Li *et al.* (2019), the total surplus gain here is noticeably smaller. This is due to a lower gross revenue at farm gate for the southern region grains industry of $2,787 million per year compared to the $3,642 million per year in the case of the western region. In addition, domestic consumers in the southern region gain a much larger share of total benefits at 13.5 per cent compared to the western region (2.4 per cent). This is attributed to the southern region having a greater volume of grains flowing domestically compared to the western region, where the vast majority of grains is directly exported to overseas markets.

Scenario 2: New processing technology in stockfeed manufacturing

The cost reduction in the other stockfeed manufacturing inputs (S_o) reduces the costs of final stockfeed destined for both the export (S_1) and domestic (S_2) markets, shifting the supply curves of these outputs downwards, reducing their prices and increasing their quantities.

The reduction in stockfeed prices brings about an increase in stockfeed usage in both the export and domestic markets. This results in upward shifts in the derived input demand for feed wheat (Z_6), barley (Z_7), peas (Z_{10}), along with canola meal (C_1) and canola directed to oilseed crushing and refining (Z_9). This in turn, triggers upward shifts in the derived input demand curves for wheat (Y_1), barley (Y_2), canola (Y_3) and peas (Y_4) directed to up-country storage, along with upward shifts in the demand curves for farm production factor inputs (X_v, X_o).

Downward shifts in the supply curves of these inputs partially offset the initial upward demand shifts. However, the demand shifts dominate these downward shifts along with any shifts due to substitution between multiple inputs for an industry segment.

The results for products in the remaining grain processing markets and export markets vary due to different input substitution and product transformation possibilities. For instance, downward supply shifts are the dominant effect for final outputs in the milling (F_1) and oilseed and crushing (C_2, C_3) markets, whereas the impacts towards malt manufacturing outputs (M_1, M_2) are negligible. In addition, an upward shift in supply is observed for export peas (Z_4), whereas movements in export wheat (Z_1), barley (Z_2) and canola (Z_3) are small.

The total surplus gain is estimated to be $3.87 million per year. Compared to Scenario 1, the gross annual benefits are smaller owing to the smaller market value of stockfeed manufacturing ($1,011 million per year) in comparison to farm production ($2,787 million per year). Another reason for the small total surplus gain is that other inputs in stockfeed manufacturing comprise only 40 per cent of total input costs $(\kappa_{So} = 0.40)$ as shown Appendix B. The share of benefits is largest for domestic consumers of stockfeed at 39.0 per cent ($1.51 million per year). This is primarily due to the assumption of inelastic domestic demand for stockfeed $(\eta_{S2,t2} = -0.5)$. In contrast, the share of benefits flowing to overseas consumers is 9.8 per cent ($0.38 million per year) as a very high export demand elasticity for stockfeed is assumed $(\eta_{S1,t1} = -4.0)$. The stockfeed manufacturing market also gains a large share of total annual benefits at 25.3 per cent ($0.98 million). This is largely due to the assumed moderate value of the input factor supply elasticity for stockfeed manufacturing $(\varepsilon_{So,to} = 1.0)$. The farm production segment only receives 14.6 per cent ($0.56 million) of the total benefits as most of the benefits are already absorbed by the stockfeed manufacturing market and domestic stockfeed consumers.

Scenario 3: Quality improvement or promotion for export wheat

An upwards shift of the demand for export wheat increases both its quantity (Z_1) and price (u_1). The increase in export demand for wheat causes the derived input demand for wheat (Y_1) to increase at the farm gate along with the input demand curves for farm inputs (X_v, X_o). The higher relative farm gate price for wheat triggers a decrease in production of barley (Y_2), canola (Y_3) and peas (Y_4). This is facilitated by a high elasticity of output transformation $(\tau = -3.0)$ between wheat and these other grain varieties in farm production.

The reduced production of barley, canola and peas brings about a decrease in the supply of the majority of outputs coming from the storage of these three grains $(Z_2, Z_3, Z_4, Z_7, Z_8, Z_9, Z_{10})$. Consequently, the supply of outputs in the malt manufacturing (M_1, M_2) and oilseed crushing and refining (C_1, C_2, C_3) markets shrink due to their reduced input supply.

The increase in wheat flowing into wheat storage subsequently results in an increase (downward shift) in the supply for export wheat (Z_1), partially offsetting the initial upwards shift in demand. Similarly, the supply of feed wheat (Z_6) also increases, which subsequently results in an increase in output supply from stockfeed manufacturing (S_1, S_2).

The supply of wheat directed to milling (Z_5) decreases due to its high level of output substitution with export wheat $(\tau_{Z1,Z5} = -3.0)$. This decreases the supply of both flour (F_1) used for domestic consumption as well as millmix (F_2) used in stockfeed manufacturing.

The supply curves of other inputs in all markets remain stationary as they are exogenous inputs to the model. The demands curves for X_v, X_o, Y_{1o} and S_o shift upwards because of the increases in export demand for wheat as well as an increase in the supply for stockfeed. Conversely, the demand curves for $Y_{2o}, Y_{3o}, Y_{4o}, F_o, M_o$ and C_o shift downwards due to the decrease in output supply in their markets.

The supply curves of grains flowing from the other cropping regions remain exogenous. However, there is now increased demand for wheat sourced from other regions (Y_5) to satisfy the higher export demand for wheat. On the other hand, demand for barley and canola sourced from other regions (Y_6, Y_7) experience negligible changes.

The estimated net surplus gain in the southern region is $16.28 million per year. This is smaller compared to the results for western region (Li *et al.*, 2019, pp. 83-88) due to the lower gross revenue of export wheat in the southern region of $1,880 million per year compared to the $2,593 million per year in the case of the western region. The majority of benefits is received by the farm sector at $8.96 million or 55.0 per cent of total benefits, due to the high export demand elasticity for wheat. The other major beneficiaries in this scenario include bulk storage ($1.81 million per year; 11.1 per cent of share), overseas wheat consumers ($4.68 million per year; 28.7 per cent of total benefits) and domestic stockfeed users ($1.09 million per year; 6.7 per cent of total benefits). In total, overseas consumers gain 27.5 per cent of the total benefits whereas domestic consumers receive 4.3 per cent of total benefits.

Summary

The simulation results show that, overall, high potential returns can be generated when targeting RD&E investments towards farm production (Scenario 1) due to the high total market value at farm gate. Similarly, as the southern grains region exports a significant proportion of total grain production, RD&E investments targeting bulk wheat exports (Scenario 3) can yield substantial returns due to the high total market value at port.

The distribution of benefits is influenced largely by the market in which the RD&E occurs, with the targeted market reaping a considerable share of total benefits. For instance, grain producers obtain a greater share of benefits from productivity-enhancing research directed on-farm (Scenario 1) rather than off-farm (Scenario 2). On the other hand, processors gain a greater share of returns when RD&E is aimed towards their own market processes rather than farm production as shown in Scenario 2. In addition, because of the high export demand elasticity for grain exports, producers can accrue large shares of benefits arising from quality-enhancing research directed at bulk wheat exports (Scenario 3).

Further Research

The results of running the model in Section 5 indicate the size and distribution of net benefits generated by different hypothetical RD&E investment decisions targeting different market segments of the industry supply chain in the region. There are several qualifications and areas for further research worth briefly outlining.

Sensitivity of results to market parameters

The model was calibrated using point estimates for the price elasticities presented in Appendix C, and the results heavily depend on the choices of these estimates. Despite careful selection of the values for these parameters used for the study, uncertainty still arises around the true values of these market parameters.

A useful solution is to apply stochastic sensitivity analysis to the estimation process by replacing point estimates for uncertain parameters with probability distributions, with the subsequent results reported as a confidence interval. Consequently, this can then identify those parameter values that have the greatest influence towards the modelled results.

In the absence of stochastic sensitivity analysis, the use of discrete sensitivity analysis can also useful in providing insights into the robustness of the results from changes in key parameter values. In the interests of brevity, these approaches have not been undertaken in this study but will be carried out in future work.

Lags in RD&E and adoption

Equilibrium Displacement Models are a form of comparative static analysis comparing the before and after equilibrium states following an exogenous shock to the system. The dynamic path of adjustment towards the new equilibrium is not captured by the models.

Exogenous shifts in the model representing the impacts of new technologies or promotions are assumed to be instantaneous and the estimated benefits reported in this study are indicative of the returns assuming full adoption and complete market adjustment (Mounter *et al*., 2008, p.80).

In reality, there is a time dimension involved in the research investment cycle. Research does not affect agricultural production directly or instantaneously. Usually a considerable time elapses before usable technologies can be generated from research investments and implemented on farm and elsewhere. As the extent of adoption increases, the size of the exogenous supply and demand shifts will also increase (Alston *et al*., 1998). Further, as with any other form of capital, the knowledge generated through agricultural research depreciates over time, and eventually becomes obsolete. Important time lags exist between commencing research, full adoption and eventual dis-adoption of an innovation or technology. An EDM alone cannot account for these dynamic adjustments.

It is proposed that further work be conducted in incorporating the nature of dynamics involved in the research investment cycle to these EDMs. This includes investigating how long it takes to develop certain research findings or products and then establishing end users' adoption responses to those various research findings and innovations. Such knowledge enables a stream of costs and benefits to be formulated so the merits of different RD&E investments can be compared.

Inter-regional framework

The EDM developed in this paper provides a regional-specific economic framework for the southern region grains industry. To be useful in informing RD&E investment decisions, this EDM should be utilised in conjunction with the WA EDM developed by Li *et al.* (2019).

This is because from a policy perspective, it can be expected that any given generic RD&E investment scenario would impact the same targetted industry segment across all cropping regions in Australia. For instance, under Scenario 1, new technologies or practices adopted from RD&E that reduce the variable costs of farm production would likely benefit farm production across all cropping regions. From a simulation point of view, this would mean that a 1 per cent downward shift in supply for variable farm production inputs (X_v) should be applied to each regional EDM, with the impacts under each EDM being summed to obtain the total impact. Though new, region-specific technologies and practices would still be modelled using the appropriate regional model.

Inter-regional feedback or spillover effects, however, cannot be readily observed under this approach. Despite the EDM providing exogenous linkages to inter-regional grain supply (Y_5, Y_6, Y_7), however, to gain a hoslitic picture of the inter-regional spillover and feedback effects of research-induced technology and demand-side improvements, an Australia-wide EDM of the grains industry that is regionally disaggregated would be required. This is an objective of future work.

Assumption of market competition

The EDM constructed in this study has the assumption that perfect competition prevails along all market segments of the industry supply chain. Since deregulation of the single-desk wheat marketing arrangements in Australia in 2008, competitiveness in the grains industry has heightened. As such, the current structure of Australia's grains industry is more likely to reflect a perfectly competitive market. Nonetheless, further work could test for market power to see whether a competitive EDM framework is realistic in the current environment.

Several studies have tested for non-competitive behaviour in the grains industry. For instance, Griffith (2000) found statistically significant evidence of non-competitive buyer power exerted by some secondary processing and marketing sectors when purchasing grains and oilseeds from farmers. This was reinforced by O'Donnell *et al*. (2007) who tested for market power in grain and oilseed industries and found evidence of oligopsonistic behaviour exhibited in various grain processing markets, including flour and food product manufacturers as well as beer and malt manufacturers. There are no such results available relating to the period since grain market deregulation.

Further investigation around market power in the upcountry storage segment of the supply chain is also warranted, given the dominant market share of Viterra and GrainCorp in the southern region grains industry. Although the Productivity Commission (2010, p. 31) determined that up-country storage facilities do not exhibit natural monopoly characteristics, further empirical analysis can be conducted. If non-competitive market characteristics are found then their characteristics could be incorporated in a revised EDM framework.

Conclusion

In this study, an EDM for the southern region grains industry encompassing South Australia, Victoria and Tasmania is developed and applied, which serves as a companion to the WA EDM presented in Li *et al.* (2019). Using the EDM, three hypothetical RD&E investment scenarios were examined in which a different market segment in the supply chain is targeted under each scenario. These scenarios relate to priorties and investment objectives outlined in the *GRDC Research, Development and Extension Plan 2018-23* (see GRDC, 2020d): optimising input costs and price improvement; reducing post-farm-gate costs; and improving trade and market access for Australian grain into export markets.

The results show that, overall, the size of the total economic benefits that results from an exogenous shift in supply or demand is determined largely by the size of the market in which the exogenous shock takes place. Therefore, investments in RD&E targeting either farm production (Scenario 1) or bulk wheat export (Scenario 3) can yield high total returns to the industry due to a substantial total market value at farm gate and port.

The distribution of benefits is mainly determined by the underlying pattern of supply and demand elasticities, but is also influenced by the market in which the RD&E occurs due to the role of substitution and transformation elasticities. As such, effective on-farm productivity research (Scenario 1) will generate a greater share of benefits to farm producers compared to effective off-farm productivity research (Scenario 2). Also, due to the high export demand elasticity for grain exports, producers can accrue large shares of benefits arising from effective quality-enhancing research directed at bulk wheat exports (Scenario 3). It is more difficult to generate large benefits from off-farm productivity research due to the generally lower cost shares of the inputs used in these sectors and the generally elastic supply of these inputs.

Compared to the simulation results for the western region presented in Li *et al.* (2019), the total surplus gain for the equivalent Scenario 1 and Scenario 3 are lower for the southern region. This is attributed to the southern region having a greater volume of grains flowing domestically compared to the western region.

In summary, this paper extends the application of the WA EDM framework to the southern region grains industry in Australia. This is useful in helping generate information that better informs agricultural RD&E investment decisions and industry actions to achieve the objectives that have been set.

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Appendix A. Definition of Variables and Parameters in the Model

Endogenous Variables	
X_v, X_o	Quantity of variable and fixed inputs used in farm production, respectively
w_v, w_o	Price of variable and fixed inputs used in farm production
X	Aggregate input index of farm production
Y_1, Y_2, Y_3, Y_4	Quantity of wheat, barley, canola and peas from farm to storage
v_1, v_2, v_3, v_4	Price of wheat, barley, canola and peas from farm to sector
Y	Aggregate output index of farm production
Y_{1o}	Quantity of other inputs used in wheat storage
v_{1o}	Price of other inputs used in wheat storage
Y_5	Quantity of inter-regional wheat inflows to wheat storage
v_5	Price of inter-regional wheat inflows to wheat storage
Y^w	Aggregate input index of wheat storage
Y_{2o}	Quantity of other inputs used in barley storage sector
v_{2o}	Price of other inputs used in the barley storage sector
Y_6	Quantity of inter-regional barley inflows to wheat storage
v_6	Price of inter-regional barley inflows to wheat storage
Y^b	Aggregate input index of barley storage
Y_{3o}	Quantity of other inputs used in canola storage sector
v_{3o}	Price of other inputs used in canola storage sector
Y_7	Quantity of inter-regional canola inflows to wheat storage
v_7	Price of inter-regional canola inflows to wheat storage
Y^c	Aggregate input index of canola storage
Y_{4o}	Quantity of other inputs used in pea storage
v_{4o}	Price of other inputs used in pea storage
Y^p	Aggregate input index of pea storage
Z_1	Quantity of wheat from wheat storage to the export market
Z_2	Quantity of barley from barley storage to the export market
Z_3	Quantity of canola from canola storage to the export market
Z_4	Quantity of peas from pea storage to the export market
Z_5, Z_6	Quantity of wheat from storage to flour milling and stock feedback manufacturing, respectively
Z_7, Z_8	Quantity of barley from storage to stockfeed manufacturing and malt manufacturing respectively
Z_9	Quantity of canola from storage to canola processing
Z_{10}	Quantity of peas from storage to stockfeed manufacturing
u_1	Price of wheat from wheat storage to the export market
u_2	Price of barley from barley storage to the export market
u_3	Price of canola from canola storage to the export market
u_4	Price of peas from pea storage to the export market
u_5, u_6	Price of wheat from storage to flour milling and stock feedback, respectively
u_7, u_8	Price of barley from storage to stockfeed manufacturing and malt manufacturing respectively
u_9	Price of canola from storage to canola processing
u_{10}	Price of peas from storage to stockfeed manufacturing
Z^w	Aggregate output index of wheat storage

Z^b	Aggregate output index of barley storage
Z^c	Aggregate output index of canola storage
Z^p	Aggregate output index of pea storage
F_o	Quantity of other inputs used in flour milling
g_o	Price of other inputs used in flour milling
Z^f	Aggregate input index of flour milling
F_1	Quantity of flour from flour milling to domestic market
g_1	Price of flour to domestic market
F_2	Quantity of Millmix from flour milling to Stockfeed Manufacturing
g_2	Price of Millmix from flour milling to Stockfeed Manufacturing
F	Aggregate output index of flour milling
S_o	Quantity of other inputs used in stockfeed manufacturing
t_o	Price of other inputs used in stockfeed manufacturing
Z^s	Aggregate input index of stockfeed manufacturing
S_1, S_2	Quantity of stockfeed to export and domestic market, respectively
t_1, t_2	Price of stockfeed to export and domestic market, respectively
S	Aggregate output index of stockfeed manufacturing
M_o	Quantity of other inputs used in malt manufacturing
n_o	Price of other inputs used in malt manufacturing
Z^m	Aggregate input index of malt manufacturing
M_1, M_2	Quantity of malt to export and domestic market, respectively
n_1, n_2	Price of malt to export and domestic market, respectively
M	Aggregate output index of malt manufacturing
C_o	Quantity of other inputs used in oilseed crushing and refining
d_o	Price of other inputs used in oilseed crushing and refining
Z^c	Aggregate input index of oilseed crushing and refining
C_1	Quantity of canola meal to stockfeed manufacturing
d_1	Price of canola meal to stockfeed manufacturing
C_2, C_3	Quantity of canola oil to export and domestic market, respectively
d_2, d_3	Prices of canola oil to export and domestic market, respectively
C	Aggregate output index of oilseed crushing and refining

Exogenous Variables

T_x:	Supply shifter shifting down supply curve of x vertically due to cost reduction in production of x ($x = X_o, X_v, Y_{1o}, Y_{2o}, Y_{3o}, Y_{4o}, Y_5, Y_6, Y_7, F_o, S_o, M_o, C_o$).
t_x:	Amount of shift T_x as a percentage of price x ($x = X_o, X_v, Y_{1o}, Y_{2o}, Y_{3o}, Y_{4o}, Y_5, Y_6, Y_7, F_o, S_o, M_o, C_o$).
N_x:	Demand shifter shifting up demand curve of x vertically due to improvements in quality or promotion that increase the demand in x ($x = Z_1, Z_2, Z_3, Z_4, F_1, S_1, S_2, M_1, M_2, C_2, C_3$).
n_x:	Amount of shift N_x as a percentage of price of x ($x = Z_1, Z_2, Z_3, Z_4, F_1, S_1, S_2, M_1, M_2, C_2, C_3$).

Parameters

$\eta_{i,j}$	Supply elasticity of commodity i with respect to price j

$\varepsilon_{i,j}$	Demand elasticity of commodity i with respect to price j
$\sigma_{i,j}$	Elasticity of substitution between inputs i and j
$\tau_{i,j}$	Elasticity of transformation between outputs i and j
κ_i	Cost share of input i
λ_i	Revenue share of output j

Appendix B. Base Equilibrium Input Values

	Quantity (000' tonnes)	Price ($/tonne)	Total Value ($m)	Cost Shares	Revenue Shares
Farm Production	$Y_1 = 7{,}306$	$v_1 = 217$	$TV_{Y1} = 1{,}588$	$\kappa_{Xv} = 0.67$	$\lambda_{Y1} = 0.57$
	$Y_2 = 3{,}566$	$v_2 = 179$	$TV_{Y2} = 640$	$\kappa_{Xo} = 0.33$	$\lambda_{Y2} = 0.23$
	$Y_3 = 1{,}053$	$v_3 = 468$	$TV_{Y3} = 493$		$\lambda_{Y3} = 0.18$
	$Y_4 = 190$	$v_4 = 347$	$TV_{Y4} = 66$		$\lambda_{Y4} = 0.02$
Up-Country Storage – Wheat	$Z_1 = 6{,}522$	$u_{s1} = 288$	$TV_{Z1} = 1{,}880$	$\kappa_{Y1o} = 0.20$	$\lambda_{Z1} = 0.80$
	$Z_5 = 665$	$u_{s5} = 267$	$TV_{Z5} = 177$	$\kappa_{Y1} = 0.68$	$\lambda_{Z5} = 0.08$
	$Z_6 = 1{,}262$	$u_{s6} = 224$	$TV_{Z6} = 283$	$\kappa_{Y5} = 0.12$	$\lambda_{Z6} = 0.12$
Up-Country Storage – Barley	$Z_2 = 2{,}397$	$u_2 = 260$	$TV_{Z2} = 624$	$\kappa_{Y2o} = 0.27$	$\lambda_{Z2} = 0.66$
	$Z_7 = 923$	$u_7 = 229$	$TV_{Z7} = 211$	$\kappa_{Y2} = 0.68$	$\lambda_{Z7} = 0.22$
	$Z_8 = 357$	$u_8 = 254$	$TV_{Z8} = 109$	$\kappa_{Y6} = 0.05$	$\lambda_{Z8} = 0.12$
Up-Country Storage – Canola	$Z_3 = 903$	$u_3 = 539$	$TV_{Z3} = 487$	$\kappa_{Y3o} = 0.74$	$\lambda_{Z3} = 0.74$
	$Z_9 = 339$	$u_9 = 518$	$TV_{Z9} = 175$	$\kappa_{Y3} = 0.11$	$\lambda_{Z9} = 0.26$
				$\kappa_{Y7} = 0.15$	
Up-Country Storage – Peas	$Z_4 = 102$	$u_4 = 418$	$TV_{Z4} = 42$	$\kappa_{Y4o} = 0.15$	$\lambda_{Z4} = 0.55$
	$Z_{10} = 102$	$u_{10} = 418$	$TV_{Z10} = 34$	$\kappa_{Y4} = 0.85$	$\lambda_{Z10} = 0.45$
Flour Milling	$F_1 = 785$	$g_1 = 620$	$TV_{F1} = 320$	$\kappa_{Fo} = 0.51$	$\lambda_{F1} = 0.89$
	$F_2 = 228$	$g_2 = 270$	$TV_{F2} = 40$	$\kappa_{Z5} = 0.49$	$\lambda_{F2} = 0.11$
Stockfeed Manufacturing	$S_1 = 785$	$t_1 = 401$	$TV_{s1} = 315$	$\kappa_{So} = 0.40$	$\lambda_{S1} = 0.31$
	$S_2 = 1{,}831$	$t_2 = 380$	$TV_{s2} = 696$	$\kappa_{Z6} = 0.28$	$\lambda_{S2} = 0.69$
				$\kappa_{Z7} = 0.21$	
				$\kappa_{Z10} = 0.03$	
				$\kappa_{F2} = 0.04$	
				$\kappa_{C1} = 0.04$	
Malt Manufacturing	$M_1 = 309$	$n_1 = 530$	$TV_{M1} = 164$	$\kappa_{Mo} = 0.46$	$\lambda_{M1} = 0.81$
	$M_2 = 77$	$n_2 = 509$	$TV_{M2} = 39$	$\kappa_{Z8} = 0.54$	$\lambda_{M2} = 0.19$
Oilseed Crushing and Refining	$C_1 = 194$	$d_1 = 220$	$TV_{C1} = 43$	$\kappa_{Co} = 0.16$	$\lambda_{C1} = 0.20$
	$C_2 = 69$	$d_2 = 1150$	$TV_{C2} = 79$	$\kappa_{Z9} = 0.84$	$\lambda_{C2} = 0.38$
	$C_3 = 76$	$d_3 = 1129$	$TV_{C3} = 86$		$\lambda_{C3} = 0.41$

Appendix C. Market Elasticity Values for the Base Run

	Demand Elasticities	**Supply Elasticities**	**Input Substitution Elasticities**	**Product Transformation Elasticities**
Farm Production		$\varepsilon_{Xv,wv} = 3.0$ $\varepsilon_{Xo,wo} = 1.0$	$\sigma_{Xv,Xo} = 0.1$	$\tau_{Y1,Y2} = -3.0$ $\tau_{Y1,Y3} = -3.0$ $\tau_{Y1,Y4} = -3.0$ $\tau_{Y2,Y3} = -3.0$ $\tau_{Y3,Y4} = -3.0$
Up-country Storage – Wheat	$\eta_{Z1,u1} = -5.0$	$\varepsilon_{Y1o,v1o} = 2.5$ $\varepsilon_{Y5,v5} = 0.5$	$\sigma_{Y1,Y1o} = 0.1$ $\sigma_{Y1,Y5} = 2$ $\sigma_{Y5,Y1o} = 0.1$	$\tau_{Z1,Z5} = -3.0$ $\tau_{Z1,Z6} = -0.5$ $\tau_{Z5,Z6} = -0.5$
Up-country Storage – Barley	$\eta_{Z2,u2} = -5.0$	$\varepsilon_{Y2o,v2o} = 2.5$ $\varepsilon_{Y6,v6} = 0.5$	$\sigma_{Y2,Y2o} = 0.1$ $\sigma_{Y2,Y6} = 2$ $\sigma_{Y6,Y2o} = 0.1$	$\tau_{Z2,Z7} = -2.0$ $\tau_{Z2,Z8} = -2.0$ $\tau_{Z7,Z8} = -0.5$
Up-country Storage – Canola	$\eta_{Z3,u3} = -5.0$	$\varepsilon_{Y3o,v3o} = 2.5$ $\varepsilon_{Y7,v7} = 0.5$	$\sigma_{Y3,Y3o} = 0.1$ $\sigma_{Y3,Y7} = 2$ $\sigma_{Y7,Y3o} = 0.1$	$\tau_{Z3,Z9} = -3.0$
Up-country Storage – Peas	$\eta_{Z4,u4} = -5.0$	$\varepsilon_{Y4o,v4o} = 2.5$	$\sigma_{Y4,Y4o} = 0.1$	$\tau_{Z4,Z10} = -3.0$
Flour Milling	$\eta_{F1,g1} = -0.5$	$\varepsilon_{Fo,go} = 1.5$	$\sigma_{Z5,Fo} = 0.1$	$\tau_{F1,F2} = -0.01$
Stockfeed Manufacturing	$\eta_{S1,t1} = -4.0$ $\eta_{S2,t2} = -0.5$	$\varepsilon_{So,to} = 1.0$	$\sigma_{Z6,Z7} = 1.0$ $\sigma_{Z6,Z10} = 1.0$ $\sigma_{Z6,F2} = 0.5$ $\sigma_{Z6,C1} = 1.0$ $\sigma_{Z6,So} = 0.1$ $\sigma_{Z7,Z10} = 1.0$ $\sigma_{Z7,F2} = 0.5$ $\sigma_{Z7,C1} = 1.0$ $\sigma_{Z7,So} = 0.1$ $\sigma_{Z10,F2} = 0.5$ $\sigma_{Z10,C1} = 1.0$ $\sigma_{Z10,So} = 0.1$ $\sigma_{F2,C1} = 0.5$ $\sigma_{F2,So} = 0.1$ $\sigma_{C1,So} = 0.1$	$\tau_{S1,S2} = -2.0$
Malt Manufacturing	$\eta_{S1,t1} = -4.0$ $\eta_{S2,t2} = -0.5$	$\varepsilon_{Mo,no} = 1.0$	$\sigma_{Z8,Mo} = 0.1$	$\tau_{M1,M2} = -2.0$
Oilseed Crushing and Refining	$\eta_{C2,d2} = -4.0$ $\eta_{C3,d3} = -0.5$	$\varepsilon_{Co,do} = 1.0$	$\sigma_{Z9,Co} = 0.1$	$\tau_{C1,C2} = -0.01$ $\tau_{C1,C3} = -0.01$ $\tau_{C2,C3} = -2.0$

Appendix D. Model Specification and the Structural Model

The product transformation functions for these three industry groups can be written as follows:

(1)	$\mathrm{Y}(\mathrm{Y}_1, \mathrm{Y}_2, \mathrm{Y}_3, \mathrm{Y}_4) = \mathrm{X}(\mathrm{X}_\mathrm{v}, \mathrm{X}_\mathrm{o})$	*farm production*
(2)	$Z^W(\mathrm{Z}_1, \mathrm{Z}_5, \mathrm{Z}_6) = Y^W(\mathrm{Y}_1, \mathrm{Y}_5, \mathrm{Y}_{1o})$	*wheat storage*
(3)	$Z^b(\mathrm{Z}_2, \mathrm{Z}_7, \mathrm{Z}_8) = \mathrm{Y}^b(\mathrm{Y}_2, \mathrm{Y}_6, \mathrm{Y}_{2o})$	*barley storage*
(4)	$Z^c(\mathrm{Z}_3, \mathrm{Z}_9) = \mathrm{Y}^c(\mathrm{Y}_3, \mathrm{Y}_7, \mathrm{Y}_{3o})$	*canola storage*
(5)	$Z^p(\mathrm{Z}_4, \mathrm{Z}_{10}) = \mathrm{Y}^p(\mathrm{Y}_4, \mathrm{Y}_{4o})$	*pea storage*
(6)	$\mathrm{F}(\mathrm{F}_1, \mathrm{F}_2,) = Z^f(\mathrm{Z}_5, \mathrm{F}_o)$	*milling*
(7)	$\mathrm{S}(\mathrm{S}_1, \mathrm{S}_2) = \mathrm{Z}^s(\mathrm{Z}_6, \mathrm{Z}_7, \mathrm{Z}_{10}, \mathrm{C}_1, \mathrm{F}_2, \mathrm{S}_o)$	*stockfeed manufacturing*
(8)	$\mathrm{M}(\mathrm{M}_1, \mathrm{M}_2) = \mathrm{Z}^m(\mathrm{Z}_8, \mathrm{M}_o)$	*malt manufacturing*
(9)	$\mathrm{C}(\mathrm{C}_1, \mathrm{C}_2, \mathrm{C}_3) = \mathrm{Z}^c(\mathrm{Z}_9, \mathrm{C}_o)$	*oilseed crushing & refining*

The variables on the left sides of the equations are outputs for the relevant industry groups and the variables on the right sides are the inputs. All the notation representing the variables and parameters in the model are defined in in Appendix A.

Cost functions related to these production functions are written as:

(10)	$\mathrm{C}_\mathrm{Y} = \mathrm{Y} * \mathrm{c}_\mathrm{Y}(w_v, w_o)$	*farm production*
(11)	$\mathrm{C}_\mathrm{Zw} = \mathrm{Z}^W * \mathrm{c}_\mathrm{Zw}(\mathrm{v}_1, \mathrm{v}_5, \mathrm{v}_{1o})$	*wheat storage*
(12)	$\mathrm{C}_\mathrm{Zb} = \mathrm{Z}^b * \mathrm{c}_\mathrm{Zb}(\mathrm{v}_2, \mathrm{v}_6, \mathrm{v}_{2o})$	*barley storage*
(13)	$\mathrm{C}_\mathrm{Zc} = \mathrm{Z}^c * \mathrm{c}_\mathrm{Zc}(\mathrm{v}_3, \mathrm{v}_7, \mathrm{v}_{3o})$	*canola storage*
(14)	$\mathrm{C}_\mathrm{Zp} = \mathrm{Z}^p * \mathrm{c}_\mathrm{Zp}(\mathrm{v}_4, \mathrm{v}_{4o})$	*pea storage*
(15)	$\mathrm{C}_\mathrm{F} = \mathrm{F} * \mathrm{c}_\mathrm{F}(\mathrm{u}_5, \mathrm{g}_o)$	*milling*
(16)	$\mathrm{C}_\mathrm{S} = \mathrm{S} * \mathrm{c}_\mathrm{S}(\mathrm{u}_6, \mathrm{u}_7, \mathrm{u}_{10}, \mathrm{d}_1, \mathrm{g}_2, \mathrm{t}_o)$	*stockfeed manufacturing*
(17)	$\mathrm{C}_\mathrm{M} = \mathrm{M} * \mathrm{c}_\mathrm{M}(\mathrm{u}_8, \mathrm{n}_o)$	*malt manufacturing*
(18)	$\mathrm{C}_\mathrm{C} = \mathrm{C} * \mathrm{c}_\mathrm{C}(\mathrm{u}_9, \mathrm{d}_o)$	*oilseed crushing & refining*

where C_x denotes the total cost of producing output index x and c_x stands for the unit cost function. Quantities are represented by capital letters and prices by lower case letters.

Similarly, the revenue functions subject to given input levels for the three multi-output industry groups can be represented as:

(19)	$\mathrm{R}_\mathrm{X} = \mathrm{X} * \mathrm{r}_\mathrm{X}(\mathrm{v}_1,\mathrm{v}_2,\mathrm{v}_3,\mathrm{v}_4)$	*farm production*
(20)	$\mathrm{R}_\mathrm{Yw} = \mathrm{Y}^w * \mathrm{r}_\mathrm{Yw}(\mathrm{u}_1,\mathrm{u}_5,\mathrm{u}_6)$	*wheat storage*
(21)	$\mathrm{R}_\mathrm{Yb} = \mathrm{Y}^b * \mathrm{r}_\mathrm{Yb}(\mathrm{u}_2,\mathrm{u}_7,\mathrm{u}_8)$	*barley storage*
(22)	$\mathrm{R}_\mathrm{Yc} = \mathrm{Y}^c * \mathrm{r}_\mathrm{Yc}(\mathrm{u}_3,\mathrm{u}_9)$	*canola storage*
(23)	$\mathrm{R}_\mathrm{Yp} = \mathrm{Y}^p * \mathrm{r}_\mathrm{Yp}(\mathrm{u}_4,\mathrm{u}_{10})$	*pea storage*
(24)	$\mathrm{R}_\mathrm{Zf} = \mathrm{Z}^f * \mathrm{r}_\mathrm{Zf}(\mathrm{g}_1,\mathrm{g}_2)$	*milling*
(25)	$\mathrm{R}_\mathrm{Zs} = \mathrm{Z}^s * \mathrm{r}_\mathrm{Zs}(\mathrm{t}_1,\mathrm{t}_2)$	*stockfeed manufacturing*
(26)	$\mathrm{R}_\mathrm{Zm} = \mathrm{Z}^m * \mathrm{r}_\mathrm{Zm}(\mathrm{n}_1,\mathrm{n}_2)$	*malt manufacturing*
(27)	$\mathrm{R}_\mathrm{Zc} = \mathrm{Z}^c * \mathrm{r}_\mathrm{Zc}(\mathrm{d}_1,\mathrm{d}_2, \mathrm{d}_3)$	*oilseed crushing & refining*

where R_x denotes the total revenue generated from the fixed input index x and r_x stands for the unit revenue function (for each $x = \mathrm{X}, \mathrm{Y}^w, \mathrm{Y}^b, \mathrm{Y}^c, \mathrm{Y}^p, \mathrm{Z}^f, \mathrm{Z}^s, \mathrm{Z}^m$ and Z^c). Similarly, quantities are represented by capital letters and prices by lower case letters.

Next, the equations representing the EDM of the southern region grains industry are specified. There are 90 equations in total, consisting of a pair of supply and demand functions for each product and a pair of equilibrium conditions in each of the nine industry groups. In addition, there are 21 exogenous variables corresponding to the products flowing into or out of the end uses (ovals) depicted in Figure 2. These exogenous variables are supply and demand shifters and represent the potential impact of new technologies and promotion. These equations expressed in general form as part of the structural model as follows:

Input supply to farm production

(28) $X_v = X_v(w_v, T_{xv})$

(29) $X_o = X_o(w_o, T_{xo})$

Output-constrained input demand of farm production

(30) $X_v = Y * c'_{Y,wv}(w_v, w_o)$

(31) $X_o = Y * c'_{Y,wo}(w_v, w_o)$

Input-constrained output supply of farm production

(32) $Y_1 = X * r'_{X,v1}(v_1, v_2, v_3, v_4)$

(33) $Y_2 = X * r'_{X,v2}(v_1, v_2, v_3, v_4)$

(34) $Y_3 = X * r'_{X,v3}(v_1, v_2, v_3, v_4)$

(35) $Y_4 = X * r'_{X,v4}(v_1, v_2, v_3, v_4)$

Equilibrium conditions of farm production

(36) $X(X_v, X_o) = Y(Y_1, Y_2, Y_3, Y_4)$

(37) $c_Y(w_v, w_o) = r_X(v_1, v_2, v_3, v_4)$

Other input supply to wheat storage

(38) $Y_{1o} = Y_{1o}(v_{1o}, T_{Y1o})$

Grain supply from other region to wheat storage

(39) $Y_5 = Y_5(v_5, T_{Y5})$

Output-constrained input demand of wheat storage

(40) $Y_1 = Z^w * c'_{Zw,v1}(v_1, v_5, v_{1o})$

(41) $Y_5 = Z^w * c'_{Zw,v5}(v_1, v_5, v_{1o})$

(42) $Y_{1o} = Z^w * c'_{Zw,v1o}(v_1, v_5, v_{1o})$

Input-constrained output supply of wheat storage

(43) $Z_1 = Y^w * r'_{Yw,u1}(u_1, u_5, u_6)$

(44) $Z_5 = Y^w * r'_{Yw,u5}(u_1, u_5, u_6)$

(45) $Z_6 = Y^w * r'_{Yw,u6}(u_1, u_5, u_6)$

Equilibrium conditions of wheat storage

(46) $Y^w(Y_1, Y_5, Y_{1o}) = Z^w(Z_1, Z_5, Z_6)$

(47) $c_{Zw}(v_1, v_5, v_{1o}) = r_{Yw}(u_1, u_5, u_6)$

Export Demand for wheat

(48) $Z_1 = Z_1(u_1, N_{Z1})$

Other input supply to barley storage

(49) $Y_{2o} = Y_{2o}(v_{2o}, T_{Y2o})$

Grain supply from other region to barley storage

(50) $Y_6 = Y_6(v_6, T_{Y6})$

Output-constrained input demand of barley storage

(51) $Y_2 = Z^b * c'_{Zb,v2}(v_2, v_6, v_{2o})$

(52) $Y_6 = Z^b * c'_{Zb,v6}(v_2, v_6, v_{2o})$

(53) $Y_{2o} = Z^b * c'_{Zb,v2o}(v_2, v_6, v_{2o})$

Input-constrained output supply of barley storage

(54) $Z_2 = Y^b * r'_{Yb,u2}(u_2, u_7, u_8)$

(55) $Z_7 = Y^b * r'_{Yb,u7}(u_2, u_7, u_8)$

(56) $Z_8 = Y^b * r'_{Yb,u8}(u_2, u_7, u_8)$

Equilibrium conditions of barley storage

(57) $Y^b(Y_2, Y_6, Y_{2o}) = Z^b(Z_2, Z_7, Z_8)$

(58) $c_{Zb}(v_2, v_6, v_{2o}) = r_{Yb}(u_2, u_7, u_8)$

Export Demand for barley

(59) $Z_2 = Z_2(u_2, N_{Z2})$

Other input supply to canola storage

(60) $Y_{3o} = Y_{3o}(v_{3o}, T_{Y3o})$

Grain supply from other regions to canola storage

(61) $Y_7 = Y_7(v_7, T_{Y7})$

Output-constrained input demand of canola storage

(62) $Y_3 = Z^c * c'_{Zc,v3}(v_3, v_7, v_{3o})$

(63) $Y_7 = Z^c * c'_{Zc,v7}(v_3, v_7, v_{3o})$

(64) $Y_{3o} = Z^c * c'_{Zc,v3o}(v_3, v_7, v_{3o})$

Input-constrained output supply of canola storage

(65) $Z_3 = Y^c * r'_{Yc,u3}(u_3, u_9)$

(66) $Z_9 = Y^c * r'_{Yc,u9}(u_3, u_9)$

Equilibrium conditions of canola storage

(67) $Y^c(Y_3, Y_7, Y_{3o}) = Z^c(Z_3, Z_9)$

(68) $c_{Zc}(v_3, v_7, v_{3o}) = r_{Yc}(u_3, u_9)$

Export Demand for canola

(69) $Z_3 = Z_3(u_3, N_{Z3})$

Other input supply to pea storage

(70) $Y_{4o} = Y_{4o}(v_{4o}, T_{Y4o})$

Output-constrained input demand of pea storage

(71) $Y_4 = Z^p * c'_{Zp,v4}(v_4, v_{4o})$

(72) $Y_{4o} = Z^p * c'_{Zp,v4o}(v_4, v_{4o})$

Input-constrained output supply of pea storage

(73) $Z_4 = Y^p * r'_{Yp,u4}(u_4, u_{10})$

(74) $Z_{10} = Y^p * r'_{Yp,u10}(u_4, u_{10})$

Equilibrium conditions of pea storage

(75) $Y^p(\mathrm{Y}_4, \mathrm{Y}_{4o}) = Z^p(\mathrm{Z}_4, \mathrm{Z}_{10})$

(76) $c_{Zp}(\mathrm{v}_4, \mathrm{v}_{1o}) = r_{Yp}(u_4, u_{10})$

Export demand of peas

(77) $Z_4 = Z_4(u_4 N_{Z4})$

Other input supply to flour milling

(78) $F_o = F_o(g_o, T_{Fo})$

Output-constrained input demand of flour milling

(79) $Z_5 = F * c'_{F,u5}(u_5, g_o)$

(80) $F_o = F * c'_{F,go}(u_5, g_o)$

Input-constrained output supply of flour milling

(81) $F_1 = Z^f * r'_{Zf,g1}(g_1, g_2)$

(82) $F_2 = Z^f * r'_{Zf,g2}(g_1, g_2)$

Equilibrium conditions of flour milling

(83) $F(\mathrm{F}_1, \mathrm{F}_2,) = \mathrm{Z}_f(\mathrm{Z}_5, \mathrm{F}_o)$

(84) $\mathrm{c_{Zf}}(\mathrm{u}_5, \mathrm{g}_o) = \mathrm{r_{Fw}}(\mathrm{g}_1,\mathrm{g}_2)$

Domestic demand of milling

(85) $F_1 = \mathrm{F}_1(\mathrm{g}_1, \mathrm{N}_{F1})$

Other input supply to stockfeed manufacturing

(86) $S_o = S_o(t_o, T_{So})$

Output-constrained input demand of stockfeed manufacturing

(87) $Z_6 = S * c'_{S,Z6}(u_6, u_7, u_{10}, d_1, g_2, t_o)$

(88) $Z_7 = S * c'_{S,Z7}(u_6, u_7, u_{10}, d_1, g_2, t_o)$

(89) $Z_{10} = S * c'_{S,Z10}(u_6, u_7, u_{10}, d_1, g_2, t_o)$

(90) $C_1 = S * c'_{S,d1}(u_6, u_7, u_{10}, d_1, g_2, t_o)$

(91) $F_2 = S * c'_{S,g2}(u_6, u_7, u_{10}, d_1, g_2, t_o)$
(92) $S_o = S * c'_{S,to}(u_6, u_7, u_{10}, d_1, g_2, t_o)$

Input-constrained output supply of stockfeed manufacturing
(93) $S_1 = Z^s * r'_{Zs,t1}(t_1, t_2)$
(94) $S_2 = Z^s * r'_{Zs,t2}(t_1, t_2)$

Equilibrium conditions of stockfeed manufacturing
(95) $Z_s(Z_6, Z_7, Z_{10}, C_1, F_2, S_o) = S(S_1, S_2)$
(96) $c_S(u_6, u_7, u_{10}, d_1, g_2, t_o) = r_{Zs}(t_1, t_2)$

Export demand of stockfeed manufacturing
(97) $S_1 = S_1(t_1, N_{S1})$

Domestic demand of stockfeed manufacturing
(98) $S_2 = S_2(t_2, N_{S2})$

Other input supply to malt manufacturing
(99) $M_o = M_o(n_o, T_{Mo})$

Output-constrained input demand of malt manufacturing
(100) $Z_8 = M * c'_{M,u8}(u_8, n_o)$
(101) $M_o = M * c'_{M,no}(u_8, n_o)$

Input-constrained output supply of malt manufacturing
(102) $M_1 = Z^m * r'_{Zm,n1}(n_1, n_2)$
(103) $M_2 = Z^m * r'_{Zm,n2}(n_1, n_2)$

Equilibrium conditions of malt manufacturing
(104) $Z_m(Z_8, M_o) = M(M_1, M_2)$
(105) $c_M(u_8, n_o) = r_{Zm}(n_1, n_2)$

Export demand of malt manufacturing
(106) $M_1 = M_1(n_1, N_{M1})$

Domestic demand of malt manufacturing
(107) $M_2 = M_2(n_2, N_{M2})$

Other input supply to oilseed crushing and refining
(108) $C_o = C_o(d_o, T_{Co})$

Output-constrained input demand of oilseed crushing and refining
(109) $Z_9 = C * c'_{C,u9}(u_9, d_o)$
(110) $C_o = C * c'_{C,do}(u_9, d_o)$

Input-constrained output supply of oilseed crushing and refining
(111) $C_1 = Z^c * r'_{Zc,d1}(d_1, d_2, d_3)$

(112) $C_2 = Z^c * r'_{Zc,d2}(d_1, d_2, d_3)$

(113) $C_3 = Z^c * r'_{Zc,d3}(d_1, d_2, d_3)$

Equilibrium conditions of oilseed crushing and refining

(114) $Z_c(Z_9, C_o) = C(C_1, C_2, C_3)$

(115) $c_C(u_9, d_o) = r_{Zc}(d_1, d_2, d_3)$

Export demand of oilseed crushing and refining

(116) $C_2 = C_2(d_2, N_{C2})$

Domestic demand of oilseed crushing and refining

(117) $C_3 = C_3(d_3, N_{C3})$

Appendix E. EDM of the Southern Region Grains Industry in Displacement Form

1. Farm Production

1.1 Input supply to farm production

(A.1) $EX_v = \varepsilon_{xv,wv} * (Ew_v - t_{xv})$

(A.2) $EX_o = \varepsilon_{xo,wo} * (Ew_o - t_{xo})$

1.2 Output constrained input demands of farm production

(A.3) $EX_v = -\kappa_{xo} * \sigma_{xv,xo} * Ew_v + \kappa_{xo} * \sigma_{xv,xo} * Ew_o + EY$

(A.4) $EX_o = -\kappa_{xv} * \sigma_{xo,xv} * Ew_o + \kappa_{xv} * \sigma_{xo,xv} * Ew_v + EY$

1.3 Input constrained output supplies of farm production

(A.5) $EY_1 = -(\lambda_{y2} * \tau_{y1,y2} + \lambda_{y3} * \tau_{y1,y3} + \lambda_{y4} * \tau_{y1,y4}) * Ev_1 + \lambda_{y2} * \tau_{y1,y2} * Ev_2 + \lambda_{y3} * \tau_{y1,y3} * Ev_3 + \lambda_{y4} * \tau_{y1,y4} * Ev_4 + EX$

(A.6) $EY_2 = -(\lambda_{y1} * \tau_{y2,y1} + \lambda_{y3} * \tau_{y2,y3} + \lambda_{y4} * \tau_{y2,y4}) * Ev_2 + \lambda_{y1} * \tau_{y2,y1} * Ev_1 + \lambda_{y3} * \tau_{y2,y3} * Ev_3 + \lambda_{y4} * \tau_{y2,y4} * Ev_4 + EX$

(A.7) $EY_3 = -(\lambda_{y1} * \tau_{y3,y1} + \lambda_{y2} * \tau_{y3,y2} + \lambda_{y4} * \tau_{y3,y4}) * Ev_3 + \lambda_{y1} * \tau_{y3,y1} * Ev_1 + \lambda_{y2} * \tau_{y3,y2} * Ev_2 + \lambda_{y4} * \tau_{y3,y4} * Ev_4 + EX$

(A.8) $EY_4 = -(\lambda_{y1} * \tau_{y4,y1} + \lambda_{y2} * \tau_{y4,y2} + \lambda_{y3} * \tau_{y4,y3}) * Ev_4 + \lambda_{y1} * \tau_{y4,y1} * Ev_1 + \lambda_{y2} * \tau_{y4,y2} * Ev_2 + \lambda_{y3} * \tau_{y4,y3} * Ev_3 + EX$

1.4 Equilibrium conditions

(A.9) $\kappa_{xv} * EX_v + \kappa_{xo} * EX_o = \lambda_{y1} * EY_1 + \lambda_{y2} * EY_2 + \lambda_{y3} * EY_3 + \lambda_{y4} * EY_4$

(A.10) $\kappa_{xv} * Ew_v + \kappa_{xo} * Ew_o = \lambda_{y1} * Ev_1 + \lambda_{y2} * Ev_2 + \lambda_{y3} * Ev_3 + \lambda_{y4} * Ev_4$

2. Wheat Storage

2.1 Input supply to wheat storage

(A.11) $EY_{1o} = \varepsilon_{y1o,v1o} * (Ev_{1o} - t_{y1o})$

2.2 Inter-regional wheat supply to wheat storage

(A.12) $EY_5 = \varepsilon_{Y5,v5} * (Ev_5 - t_{Y5})$

2.2 Output constrained input demands of wheat storage

(A.13) $EY_1 = -(\kappa_{Y1o} * \sigma_{Y1,Y1o} + \kappa_{Y5} * \sigma_{Y1,Y5}) * Ev_1 + \kappa_{Y1o} * \sigma_{Y1,Y1o} * Ev_{1o} + \kappa_{Y5} * \sigma_{Y1,Y5} * Ev_5 + EZ^w$

(A.14) $EY_5 = -(\kappa_{Y1} * \sigma_{Y1,Y5} + \kappa_{Y1o} * \sigma_{Y5,Y1o}) * Ev_5 + \kappa_{Y1} * \sigma_{Y1,Y5} * Ev_1 + \kappa_{Y1o} * \sigma_{Y5,Y1o} * Ev_{1o} + EZ^w$

(A.15) $EY_{1o} = -(\kappa_{Y1} * \sigma_{Y1,Y1o} + \kappa_{Y5} * \sigma_{Y5,Y1o}) * Ev_{1o} + \kappa_{Y1} * \sigma_{Y1,Y1o} * Ev_1 + \kappa_{Y5} * \sigma_{Y5,Y1o} * Ev_5 + EZ^w$

2.3 Input constrained output supply of wheat storage

(A.16) $EZ_1 = -(\lambda_{z5} * \tau_{z1,z5} + \lambda_{z6} * \tau_{z1,z6}) * Eu_1 + \lambda_{z5} * \tau_{z1,z5} * Eu_5 + \lambda_{z6} * \tau_{z1,z6} * Eu_6 + EY^w$

(A.17) $EZ_5 = -(\lambda_{z1} * \tau_{z5,z1} + \lambda_{z6} * \tau_{z5,z6}) * Eu_5 + \lambda_{z1} * \tau_{z5,z1} * Eu_1 + \lambda_{z6} * \tau_{z5,z6} * Eu_6 + EY^w$

(A.18) $EZ_6 = -(\lambda_{z1} * \tau_{z6,z1} + \lambda_{z5} * \tau_{z6,z5}) * Eu_6 + \lambda_{z1} * \tau_{z6,z1} * Eu_1 + \lambda_{z5} * \tau_{z6,z5} * Eu_5 + EY^w$

2.4 Equilibrium conditions

(A.19) $\kappa_{Y1} * EY_1 + \kappa_{Y5} * EY_5 + \kappa_{Y1o} * EY_{1o} = \lambda_{Z1} * EZ_1 + \lambda_{Z5} * EZ_5 + \lambda_{Z6} * EZ_6$

(A.20) $\kappa_{v1} * Ev_1 + \kappa_{v5} * Ev_5 + \kappa_{v1o} * Ev_{1o} = \lambda_{u1} * Eu_1 + \lambda_{u5} * Eu_5 + \lambda_{u6} * Eu_6$

2.5 Export Demand

(A.21) $EZ_1 = \eta_{z1,u1} * (Eu_1 - n_{z1})$

3. Barley Storage

3.1 Input supply to barley storage

(A.22) $EY_{2o}=\varepsilon_{y2o,v2o}*(Ev_{2o} - t_{y2o})$

3.2 Inter-regional barley supply to barley storage

(B.23) $EY_6=\varepsilon_{Y6,v6}*(Ev_6 - t_{Y6})$

3.2 Output constrained input demands of barley storage

(A.24) $EY_2 = -(\kappa_{Y2o} * \sigma_{Y2,Y2o} + \kappa_{Y6} * \sigma_{Y2,Y6}) * Ev_2 + \kappa_{Y2o} * \sigma_{Y2,Y2o} * Ev_{2o} + \kappa_{Y6} * \sigma_{Y2,Y6} * Ev_6 + EZ^b$

(B.25) $EY_6 = -(\kappa_{Y2} * \sigma_{Y2,Y6} + \kappa_{Y2o} * \sigma_{Y6,Y2o}) * Ev_6 + \kappa_{Y2} * \sigma_{Y2,Y6} * Ev_2 + \kappa_{Y2o} * \sigma_{Y6,Y2o} * Ev_{2o} + EZ^b$

(A.26) $EY_{2o} = -(\kappa_{Y2} * \sigma_{Y2,Y2o} + \kappa_{Y6} * \sigma_{Y6,Y2o}) * Ev_{2o} + \kappa_{Y2} * \sigma_{Y2,Y2o} * Ev_2 + \kappa_{Y6} * \sigma_{Y6,Y2o} * Ev_6 + EZ^b$

3.3 Input constrained output supply of barley storage

(A.27) $EZ_2 = -(\lambda_{z7} * \tau_{z2,z7} + \lambda_{z8} * \tau_{z2,z8}) * Eu_2 + \lambda_{z7} * \tau_{z2,z7} * Eu_7 + \lambda_{z8} * \tau_{z2,z8} * Eu_8 + EY^b$

(A.28) $EZ_7 = -(\lambda_{z2} * \tau_{z7,z2} + \lambda_{z8} * \tau_{z7,z8}) * Eu_7 + \lambda_{z2} * \tau_{z7,z2} * Eu_2 + \lambda_{z8} * \tau_{z7,z8} * Eu_8 + EY^b$

(A.29) $EZ_8 = -(\lambda_{z2} * \tau_{z8,z2} + \lambda_{z7} * \tau_{z8,z7}) * Eu_8 + \lambda_{z2} * \tau_{z8,z2} * Eu_2 + \lambda_{z7} * \tau_{z8,z7} * Eu_7 + EY^b$

3.4 Equilibrium conditions

(A.30) $\kappa_{Y2} * EY_2 + \kappa_{Y6} * EY_6 + \kappa_{Y2o} * EY_{2o} = \lambda_{Z2} * EZ_2 + \lambda_{Z7} * EZ_7 + \lambda_{Z8} * EZ_8$

(A.31) $\kappa_{v2} * Ev_2 + \kappa_{v6} * Ev_6 + \kappa_{v2o} * Ev_{2o} = \lambda_{u2} * Eu_2 + \lambda_{u7} * Eu_7 + \lambda_{u8} * Eu_8$

3.5 Export Demand

(A.32) $EZ_2 = \eta_{z2,u2} * (Eu_2 - n_{z2})$

4. Canola Storage

4.1 Input supply to canola storage

(A.33) $\mathrm{EY}_{3o}=\varepsilon_{y3o,v3o}*(\mathrm{Ev}_{3o}-\mathrm{t}_{y3o})$

4.2 Inter-regional canola supply to canola storage

(B.34) $\mathrm{EY}_{7}=\varepsilon_{Y7,v7}*(\mathrm{Ev}_{7}-\mathrm{t}_{Y7})$

4.2 Output constrained input demands of canola storage

(B.35) $\mathrm{EY}_3=-(\kappa_{Y3o}*\sigma_{Y3,Y3o}+\kappa_{Y7}*\sigma_{Y3,Y7})*\mathrm{Ev}_3+\kappa_{Y3o}*\sigma_{Y3,Y3o}*\mathrm{Ev}_{3o}+\kappa_{Y7}*\sigma_{Y3,Y7}*\mathrm{Ev}_7+\mathrm{E}Z^c$

(B.36) $\mathrm{EY}_7=-(\kappa_{Y3}*\sigma_{Y3,Y7}+\kappa_{Y3o}*\sigma_{Y7,Y3o})*\mathrm{Ev}_7+\kappa_{Y3}*\sigma_{Y3,Y7}*\mathrm{Ev}_3+\kappa_{Y3o}*\sigma_{Y7,Y3o}*\mathrm{Ev}_{3o}+\mathrm{E}Z^c$

(B.37) $\mathrm{EY}_{3o}=-(\kappa_{Y3}*\sigma_{Y3,Y3o}+\kappa_{Y7}*\sigma_{Y7,Y3o})*\mathrm{Ev}_{3o}+\kappa_{Y3}*\sigma_{Y3,Y3o}*\mathrm{Ev}_3+\kappa_{Y7}*\sigma_{Y7,Y3o}*\mathrm{Ev}_7+\mathrm{E}Z^c$

4.3 Input constrained output supply of canola storage

(A.38) $\mathrm{EZ}_3=-\lambda_{z9}*\tau_{z3,z9}*\mathrm{Eu}_3+\lambda_{z9}*\tau_{z3,z9}*\mathrm{Eu}_9+\mathrm{E}Y^c$

(A.39) $\mathrm{EZ}_9=-\lambda_{z3}*\tau_{z9,z3}*\mathrm{Eu}_9+\lambda_{z3}*\tau_{z9,z3}*\mathrm{Eu}_3+\mathrm{E}Y^c$

4.4 Equilibrium conditions

(A.40) $\kappa_{Y3}*\mathrm{EY}_3+\kappa_{Y7}*\mathrm{EY}_7+\kappa_{Y3o}*\mathrm{EY}_{3o}=\lambda_{Z3}*\mathrm{EZ}_3+\lambda_{Z9}*\mathrm{EZ}_9$

(A.41) $\kappa_{v3}*\mathrm{Ev}_3+\kappa_{v7}*\mathrm{Ev}_7+\kappa_{v3o}*\mathrm{Ev}_{3o}=\lambda_{u3}*\mathrm{Eu}_3+\lambda_{u9}*\mathrm{Eu}_9$

4.5 Export Demand

(A.42) $\mathrm{EZ}_3=\eta_{z3,u3}*(\mathrm{Eu}_3-n_{z3})$

5. Pea Storage

5.1 Input supply to pea storage

(A.43) $\mathrm{EY}_{4o}=\varepsilon_{y4o,v4o}*(\mathrm{Ev}_{4o}-\mathrm{t}_{y4o})$

5.2 Output constraints input demands of pea storage

(A.44) $\mathrm{EY}_4=-\kappa_{y4o}*\sigma_{y4,y4o}*\mathrm{Ev}_4+\kappa_{y4o}*\sigma_{y4,y4o}*\mathrm{Ev}_{4o}+\mathrm{E}Z^l$

(A.45) $\mathrm{EY}_{4o}=-\kappa_{y4}*\sigma_{Y4o,Y4}*\mathrm{Ev}_{4o}+\kappa_{y4}*\sigma_{y4o,y4}*\mathrm{Ev}_4+\mathrm{E}Z^l$

5.3 Input constrained output supply of pea storage

(A.46) $\mathrm{EZ}_4=-\lambda_{z10}*\tau_{z4,z10}*\mathrm{Eu}_4+\lambda_{z10}*\tau_{z4,z10}*\mathrm{Eu}_{10}+\mathrm{E}Y^l$

(A.47) $\mathrm{EZ}_{10}=-\lambda_{z4}*\tau_{z10,z4}*\mathrm{Eu}_{10}+\lambda_{z4}*\tau_{z10,z4}*\mathrm{Eu}_4+\mathrm{E}Y^l$

5.4 Equilibrium conditions

(A.48) $\kappa_{Y4} * EY_4 + \kappa_{Y4o} * EY_{4o} = \lambda_{Z4} * EZ_4 + \lambda_{Z10} * EZ_{10}$

(A.49) $\kappa_{v4} * Ev_4 + \kappa_{v4o} * Ev_{4o} = \lambda_{u4} * Eu_4 + \lambda_{u10} * Eu_{10}$

5.5 Export Demand

(A.50) $EZ_4 = \eta_{z4,u4} * (Eu_4 - n_{z4})$

6. Flour Milling

6.1 Input supply to flour milling

(A.51) $EF_o = \varepsilon_{Fo,go} * (Eg_o - t_{Fo})$

6.2 Output constrained input demand of flour milling

(A.52) $EZ_5 = -\kappa_{Fo} * \sigma_{Z5,Fo} * Eu_5 + \kappa_{Fo} * \sigma_{Z5,Fo} * Eg_o + EF$

(A.53) $EF_o = -\kappa_{Z5} * \sigma_{Fo,Z5} * Eg_o + \kappa_{Z5} * \sigma_{Fo,Z5} * Eu_5 + EF$

6.3 Input constrained output supply of flour milling

(A.54) $EF_1 = -\lambda_{F2} * \tau_{F1,F2} * Eg_1 + \lambda_{F2} * \tau_{F1,F2} * Eg_2 + EZ^f$

(A.55) $EF_2 = -\lambda_{F1} * \tau_{F2,F1} * Eg_2 + \lambda_{F1} * \tau_{F2,F1} * Eg_1 + EZ^f$

6.4 Equilibrium conditions

(A.56) $\kappa_{Z5} * EZ_5 + \kappa_{Fo} * EF_o = \lambda_{F1} * EF_1 + \lambda_{F2} * EF_2$

(A.57) $\kappa_{u5} * Eu_5 + \kappa_{go} * Eg_o = \lambda_{g1} * Eg_1 + \lambda_{g2} * Eg_2$

6.5 Domestic demand

(A.58) $EF_1 = \eta_{F1,g1} * (g_1 - n_{F1})$

7. Stockfeed Manufacturing

7.1 Input supply to stockfeed manufacturing

(A.59) $ES_o = \varepsilon_{So,to} * (Et_o - t_{So})$

7.2 Output constrained input demand of stockfeed manufacturing

(A.60) $EZ_6 = -(\kappa_{Z7} * \sigma_{Z6,Z7} + \kappa_{Z10} * \sigma_{Z6,Z10} + \kappa_{C1} * \sigma_{Z6,C1} + \kappa_{F2} * \sigma_{Z6,F2} + \kappa_{So} * \sigma_{Z6,So}) * Eu_6 + \kappa_{Z7} * \sigma_{Z6,Z7} * Eu_7 + \kappa_{Z10} * \sigma_{Z6,Z10} * Eu_{10} + \kappa_{C1} * \sigma_{Z6,C1} * Ed_1 + \kappa_{F2} * \sigma_{Z6,F2} * Eg_2 + \kappa_{So} * \sigma_{Z6,So} * Et_o + ES$

(A.61) $EZ_7 = -(\kappa_{Z6} * \sigma_{Z7,Z6} + \kappa_{Z10} * \sigma_{Z7,Z10} + \kappa_{C1} * \sigma_{Z7,C1} + \kappa_{F2} * \sigma_{Z7,F2} + \kappa_{So} * \sigma_{Z7,So}) * Eu_7 + \kappa_{Z6} * \sigma_{Z7,Z6} * Eu_6 + \kappa_{Z10} * \sigma_{Z7,Z10} * Eu_{10} + \kappa_{C1} * \sigma_{Z7,C1} * Ed_1 + \kappa_{F2} * \sigma_{Z7,F2} * Eg_2 + \kappa_{So} * \sigma_{Z7,So} * Et_o + ES$

(A.62) $EZ_{10} = -(\kappa_{Z6} * \sigma_{Z10,Z6} + \kappa_{Z7} * \sigma_{Z10,Z7} + \kappa_{C1} * \sigma_{Z10,C1} + \kappa_{F2} * \sigma_{Z10,F2} + \kappa_{So} * \sigma_{Z10,So}) * Eu_{10} + \kappa_{Z6} * \sigma_{Z10,Z6} * Eu_6 + \kappa_{Z7} * \sigma_{Z10,Z7} * Eu_7 + \kappa_{C1} * \sigma_{Z10,C1} * Ed_1 + \kappa_{F2} * \sigma_{Z10,F2} * Eg_2 + \kappa_{So} * \sigma_{Z10,So} * Et_o + ES$

(A.63) $EC_1 = -(\kappa_{Z6} * \sigma_{C1,Z6} + \kappa_{Z7} * \sigma_{C1,Z7} + \kappa_{Z10} * \sigma_{C1,Z10} + \kappa_{F2} * \sigma_{C1,F2} + \kappa_{So} * \sigma_{C1,So}) * Ed_1 + \kappa_{Z6} * \sigma_{C1,Z6} * Eu_6 + \kappa_{Z7} * \sigma_{C1,Z7} * Eu_7 + \kappa_{Z10} * \sigma_{C1,Z10} * Eu_{10} + \kappa_{F2} * \sigma_{C1,F2} * Eg_2 + \kappa_{So} * \sigma_{C1,So} * Et_o + ES$

(A.64) $EF_2 = -(\kappa_{Z6} * \sigma_{F2,Z6} + \kappa_{Z7} * \sigma_{F2,Z7} + \kappa_{Z10} * \sigma_{F2,Z10} + \kappa_{C1} * \sigma_{F2,C1} + \kappa_{So} * \sigma_{F2,So}) * Eg_2 + \kappa_{Z6} * \sigma_{F2,Z6} * Eu_6 + \kappa_{Z7} * \sigma_{F2,Z7} * Eu_7 + \kappa_{Z10} * \sigma_{F2,Z10} * Eu_{10} + \kappa_{C1} * \sigma_{F2,C1} * Ed_1 + \kappa_{So} * \sigma_{F2,So} * Et_o + ES$

(A.65) $ES_o = -(\kappa_{Z6} * \sigma_{So,Z6} + \kappa_{Z7} * \sigma_{So,Z7} + \kappa_{Z10} * \sigma_{So,Z10} + \kappa_{C1} * \sigma_{So,C1} + \kappa_{F2} * \sigma_{So,F2}) * Et_o + \kappa_{Z6} * \sigma_{F2,Z6} * Eu_6 + \kappa_{Z7} * \sigma_{F2,Z7} * Eu_7 + \kappa_{Z10} * \sigma_{F2,Z10} * Eu_{10} + \kappa_{C1} * \sigma_{F2,C1} * Ed_1 + \kappa_{So} * \sigma_{F2,So} * Et_o + ES$

7.3 Input constrained output supply of stockfeed manufacturing

(A.66) $ES_1 = -\lambda_{S2} * \tau_{S1,S2} * Et_1 + \lambda_{S2} * \tau_{S1,S2} * Et_2 + EZ^s$

(A.67) $ES_2 = -\lambda_{S1} * \tau_{S2,S1} * Et_2 + \lambda_{S1} * \tau_{S2,S1} * Et_1 + EZ^s$

7.4 Equilibrium conditions

(A.68) $\kappa_{Z6} * EZ_6 + \kappa_{Z7} * EZ_7 + \kappa_{Z10} * EZ_{10} + \kappa_{C1} * EC_1 + \kappa_{F2} * EF_2 + \kappa_{So} * ES_o = \lambda_{S1} * ES_1 + \lambda_{S2} * ES_2$

(A.69) $\kappa_{u6} * Eu_6 + \kappa_{u7} * Eu_7 + \kappa_{u10} * Eu_{10} + \kappa_{d1} * Ed_1 + \kappa_{g2} * Eg_2 + \kappa_{to} * Et_o = \lambda_{t1} * Et_1 + \lambda_{t2} * Et_2$

7.5 Export demand

(A.70) $ES_1 = \eta_{S1,t1} * (t_1 - n_{S1})$

7.6 Domestic demand

(A.71) $ES_2 = \eta_{S2,t2} * (t_2 - n_{S2})$

8. Malt Manufacturing

8.1 Input supply to malt manufacturing

(A.72) $EM_o = \varepsilon_{Mo,no} * (En_o - t_{Mo})$

8.2 Output constrained input demand of malt manufacturing

(A.73) $EZ_8 = -\kappa_{Mo} * \sigma_{Z8,Mo} * Eu_8 + \kappa_{Mo} * \sigma_{Z8,Mo} * En_o + EM$

(A.74) $EM_o = -\kappa_{Z8} * \sigma_{Mo,Z8} * En_o + \kappa_{Z8} * \sigma_{Mo,Z8} * Eu_8 + EM$

8.3 Input constrained output supply of malt manufacturing

(A.75) $EM_1 = -\lambda_{M2} * \tau_{M1,M2} * En_1 + \lambda_{M2} * \tau_{M1,M2} * En_2 + EZ^m$

(A.76) $\mathrm{EM}_2 = -\lambda_{M1} * \tau_{M2,M1} * \mathrm{En}_2 + \lambda_{M1} * \tau_{M2,M1} * \mathrm{En}_1 + \mathrm{EZ}^{\mathrm{m}}$

8.4 Equilibrium conditions

(A.77) $\kappa_{Z8} * \mathrm{EZ}_8 + \kappa_{Mo} * \mathrm{EM}_o = \lambda_{M1} * \mathrm{EM}_1 + \lambda_{M2} * \mathrm{EM}_2$

(A.78) $\kappa_{u8} * \mathrm{Eu}_8 + \kappa_{no} * \mathrm{En}_o = \lambda_{n1} * \mathrm{En}_1 + \lambda_{n2} * \mathrm{En}_2$

8.5 Export demand

(A.79) $\mathrm{EM}_1 = \eta_{M1,t1} * (\mathrm{t}_1 - n_{M1})$

8.6 Domestic demand

(A.80) $\mathrm{EM}_2 = \eta_{M2,t2} * (\mathrm{t}_2 - n_{M2})$

9. Oilseed Crushing and Refining

9.1 Input supply to oilseed crushing and refining

(A.81) $\mathrm{EC}_o = \varepsilon_{Co,do} * (\mathrm{Ed}_o - \mathrm{t}_{Co})$

9.2 Output constrained input demand of oilseed crushing and refining

(A.82) $\mathrm{EZ}_9 = -\kappa_{Co} * \sigma_{Z9,Co} * \mathrm{Eu}_9 + \kappa_{Co} * \sigma_{Z9,Co} * \mathrm{Ed}_o + \mathrm{EC}$

(A.83) $\mathrm{EC}_o = -\kappa_{Z9} * \sigma_{Co,Z9} * \mathrm{Ed}_o + \kappa_{Z9} * \sigma_{Co,Z9} * \mathrm{Eu}_9 + \mathrm{EC}$

9.3 Input constrained output supply of oilseed crushing and refining

(A.84) $\mathrm{EC}_1 = -(\lambda_{C2} * \tau_{C1,C2} + \lambda_{C3} * \tau_{C1,C3}) * \mathrm{Ed}_1 + \lambda_{C2} * \tau_{C1,C2} * \mathrm{Ed}_2 + \lambda_{C3} * \tau_{C1,C3} * \mathrm{Ed}_3 + \mathrm{EZ}^{\mathrm{c}}$

(A.85) $\mathrm{EC}_2 = -(\lambda_{C1} * \tau_{C2,C1} + \lambda_{C3} * \tau_{C2,C3}) * \mathrm{Ed}_2 + \lambda_{C1} * \tau_{C2,C1} * \mathrm{Ed}_1 + \lambda_{C3} * \tau_{C2,C3} * \mathrm{Ed}_3 + \mathrm{EZ}^{\mathrm{c}}$

(A.86) $\mathrm{EC}_3 = -(\lambda_{C1} * \tau_{C3,C1} + \lambda_{C2} * \tau_{C3,C2}) * \mathrm{Ed}_3 + \lambda_{C1} * \tau_{C3,C1} * \mathrm{Ed}_1 + \lambda_{C2} * \tau_{C3,C2} * \mathrm{Ed}_2 + \mathrm{EZ}^{\mathrm{c}}$

9.4 Equilibrium conditions

(A.87) $\kappa_{Z9} * \mathrm{EZ}_9 + \kappa_{Co} * \mathrm{EC}_o = \lambda_{C1} * \mathrm{EC}_1 + \lambda_{C2} * \mathrm{EC}_2 + \lambda_{C3} * \mathrm{EC}_3$

(A.88) $\kappa_{u9} * \mathrm{Eu}_9 + \kappa_{do} * \mathrm{Ed}_o = \lambda_{d1} * \mathrm{Ed}_1 + \lambda_{d2} * \mathrm{Ed}_2 + \lambda_{d3} * \mathrm{Ed}_3$

9.5 Export demand

(A.89) $\mathrm{EC}_2 = \eta_{C2,d2} * (\mathrm{d}_2 - n_{C2})$

9.6 Domestic demand

(A.90) $\mathrm{EC}_3 = \eta_{C3,d3} * (\mathrm{d}_3 - n_{d3})$