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Measuring the Potential Returns to Research, Development and Extension in the Australian Grains Industry

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Abstract

The Australian grains industry is fundamental to the overall agricultural sector, comprising one of Australia's largest category of food exports. Over recent decades, the grains industry has faced challenges. Its total factor productivity growth has slowed due to factors such as climate change, extreme weather events, declining research, development and extension, and slower adoption of new technologies. This has been coupled with greater competition in Australia's main grain export markets. In order to increase productivity and maintain international competitiveness, greater and better-targeted investments in research, development and extension and market intelligence are required.

Equilibrium Displacement Models (EDMs) are useful for estimating the net benefits of agricultural RD&E and the distribution of these benefits along the value chain, enabling an evaluation of different research investments. This thesis develops three EDMs, one for each main agroecological region in Australia—the Western, Southern and Northern regions. Combined together, these models provide a stylised representation of the Australian grains industry and can be applied to assist investment decisions by RD&E funders and other parties seeking to boost the profitability of various parts of Australia's grains industry.

Eight hypothetical RD&E investment scenarios are modelled for each region, depicted by one per cent exogenous parallel shifts in the relevant market supply and demand curves associated with each region. Under each investment scenario for each region, both the change in total economic surplus as well as the welfare changes in each of the different industry sectors are estimated.

It is found that, overall, the size of the total economic benefits is determined largely by the size of the market in which the RD&E investment takes place, with a high gross revenue market generating higher overall returns. Additionally, the size of the innovating market also impacts the distribution of benefits, as the larger the gross value of this market, the greater its share of total benefits received.

The results generally suggest that producers receive a greater share of benefits from on-farm research than from off-farm research. They also receive comparably large shares from export market research and promotion. Differences in results are also observed between the three regions. Due to regional differences in supply chain characteristics, any particular RD&E investment scenario will affect each region differently. Stochastic sensitivity analysis is also conducted for the uncertain market parameter values specified in the base model.

Using the set of EDMs to generate information that better informs agricultural research, development and extension investment decisions and industry actions, can ultimately boost the economic role and performance of Australia's grains industry.

Declaration

This is to certify that:

- i. this thesis comprises only my original work towards the degree of Doctor of Philosophy, except where indicated in the preface;*
- ii. due acknowledgement has been made in the text to all other material used; and*
- iii. this thesis is less than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.*



.....

Kuo Li

Preface

This thesis contains content from the following publications:

Li, K., Kingwell, R., Griffith, G., & Malcolm, B. (2018). Issues in measuring returns from RD&E investments in the Australian grains industry. *Australasian Agribusiness Perspectives*, 21(15), 246-282.

Li, K., Kingwell, R., Griffith, G., & Malcolm, B. (2019). Measuring the returns to investment in RD&E; in the WA grains industry using equilibrium displacement modelling. *Australasian Agribusiness Review*, 27(4), 65-106.

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List of Acronyms and Abbreviations

ABARES	Australian Bureau of Agricultural and Resource Economics and Science
ABS	Australian Bureau of Statistics
ACF	Australian Crop Forecasters
AEGIC	Australian Export Grains Innovation Centre
AWB	Australian Wheat Board
EDM	Equilibrium Displacement Model
FAO	The Food and Agriculture Organization of the United Nations
GRDC	Grains Research and Development Corporation
RDC	Research and Development Corporation
RD&E	Research, Development and Extension
USDA	United States Department of Agriculture

Chapter 1 Introduction

1.1 Background and Motivation

The Australian grains industry is one of the most important agricultural components of the Australian economy. Over \$14 billion worth of exports was recorded during 2016-17 for the three main categories of grains – cereal grains, oilseeds and pulses, representing nearly 30 per cent of total farm export income during that financial year (ABARES, 2017).

The Australian grains industry has evolved and grown markedly over the past 30 years, supported by changing markets and an average annual growth in total factor productivity of 1.5 per cent (Boult & Chancellor, 2019). Structural adjustments to the industry during this period included 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.

Challenges have emerged however. Since the 1990s, 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 research, development and extension (RD&E), a re-direction of research priorities away from enhancing farm productivity, and a slower adoption of new technologies (Hockman, Gobbett, & Horan, 2017; Primary Industries Standing Committee, 2011).

Productivity is measured by the quantity of outputs produced for a given quantity of inputs, with higher long term productivity growth contributing to greater profitability and competitiveness. This has played a key role in sustaining profitability in the Australian grains industry, given the long-term decline in growers' terms of trade that has seen the prices received for farm products decline relative to input prices (Primary Industries Standing Committee, 2011). Productivity growth is also vital in maintaining the competitiveness of Australian grain in an increasingly competitive global grain market, as emerging competitors from the Black Sea Region and Argentina now pose a challenge for Australia's key export markets in Asia (Kingwell, 2019).

It is understood that RD&E and innovation are key drivers to enhancing productivity in the industry (GRDC, 2020). Recognising the need for improvement in order to maintain international competitiveness, the Grains Industry National Research, Development and Extension Strategy aims to achieve an annual growth in total factor productivity of more than 2.5 per cent by 2025 (Research and Innovation Committee, 2017). Such an achievement would require greater and better-targeted investments in RD&E.

RD&E funding is sourced from both the public and private sectors. Public sector funding includes contributions from the Commonwealth Government, State and Territory governments and universities. Private sector funding consists of contributions from grain growers through compulsory levies to the Grains Research and Development Corporation (GRDC), along with privately funded research and development.

The GRDC is a Commonwealth statutory research and development corporation (RDC) that invests in RD&E with the aim to enhance the grains industry's profitability and productivity. The GRDC is based on a co-funding partnership between industry and the Commonwealth Government. Levy contributions to the GRDC are substantial. In 2014-15, it was estimated that around \$117.6 million of levies were raised from grain growers, representing around 40 per cent of total levy contributions from all RDCs, which was supplemented by a further \$67.8 million in Commonwealth matching funding (Millist *et al.*, 2017). In terms of the allocation of this funding, it was estimated that the majority (55%) was invested in research on productivity and adding value, followed by biosecurity (18%), innovation skills (10%), natural resource management (8%), supply chain and markets (5%) and climate (3%) (Millist *et al.*, 2017).

Allocating funding to RD&E poses challenges and trade-offs. Decisions must be made about how much funding to allocate to research projects, with different investment decisions having different potential distributional effects. Funding agencies and producers alike have a vested interest in the efficient allocation of funds to maximise their returns. The Grains Industry National RD&E Strategy (Research and Innovation Committee, 2017, p.30) notes that '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.' To evaluate the merits of a particular research investment, it is necessary to know the total size of the benefits stemming from research, and also the distribution of benefits among the participants in the whole value chain. An Equilibrium Displacement Model (EDM) framework can help address these questions.

1.2 Objective of the Study

The objective of the study is to develop a system of economic models for the Australian grains industry, one for each agroecological region of western, southern and northern Australia. Each model provides a stylised representation of the regional industry, accounting for the relationships between the main market sectors, including: farm production, secondary processing, and domestic and export distribution. The specific objectives of this study are to:

- provide a holistic economic framework to estimate and compare the potential benefits from various RD&E investments both within each grain cropping region as well as between different regions; and
- estimate the distribution of the total benefits arising from a hypothetical set of RD&E investment scenarios, among all the different industry participants along the value chains of each region.

1.3 Method

The method used in this study is equilibrium displacement modelling (EDM). First coined by Piggott (1992), EDMs are a comparative static modelling approach that involves representing the industry of focus by a system of supply and demand equations, expressed in log difference form. A set of base market prices and quantities are used to establish the initial equilibrium in the industry. The impacts of RD&E investments then are modelled as exogenous shocks to the system which result in changes or ‘displacements’ in the market prices and quantities. Market elasticities are used to determine the responsiveness of production and consumption, with respect to changes in prices. Once solved, the system is then brought to a new equilibrium point. The consequential changes to producer and consumer surpluses are then estimated as welfare changes to the various sectors of the industry. Stochastic sensitivity analysis is also conducted to address the uncertainty associated with market elasticities.

Here, the structure of the Australian grains Industry is specified within an EDM framework. Each agroecological region is represented by a standalone EDM that captures the stylised value chain distinctive to that region. Each region is distinguished by its distinctive set and mix of grain commodities produced, its secondary processing sectors and its distribution paths to domestic and export markets. There are three EDMs presented in this study capturing the western, southern and

northern agroecological regions as defined by the GRDC. Each regional industry consists of a multi-stage production system consisting of numerous horizontal and vertical market segments. Horizontally, each regional industry is disaggregated into the stages of farm production, up-country storage and handling, secondary processing and domestic and export markets. Vertically, the industry is disaggregated into farm production, storage, processing (milling, stockfeed manufacturing, malt manufacturing, oilseed crushing and refining), and consumption.

The EDM in this study uses changes in economic surplus (both consumer and producer surplus) to measure welfare changes to the various sectors of the industry. This method of analysis follows the approach adopted by Zhao *et al.* (2000b) and Mounter *et al.* (2008).

1.4 Significance of the Study

The relationship between investments in agricultural RD&E and agricultural productivity has been long studied. Governments and funding agencies are bound to demonstrate the potential welfare impacts of research programs to justify their investments, as well as to prioritise future research. Payers of RD&E levies hold the expectation that their contributions are optimally allocated to maximise the returns to the industry and farmers alike. However, estimating the economic benefits of investment in agricultural RD&E and the distribution of net benefits has conceptual, methodological and practical challenges.

An EDM can reveal the net benefits of an increase in productivity or reduction in costs in grain production, at the farm level or elsewhere in the value chain from innovations that are expected to result from RD&E investments. In addition, they can also estimate the distribution of net benefits between producers and other participants in the value chain.

EDMs have numerous applications in agricultural policy analysis and have been developed for a number of agricultural industries in Australia, mostly in the livestock industries such as beef (Zhao, Mullen, Griffith, Griffiths, & Piggott, 2000), sheep and wool (Mounter *et al.*, 2008), pig (Mounter, Griffith, & Piggott, 2004), and dairy (Liu, Tarrant, Ho, Malcolm, & Griffith, 2012; Ludemann, Griffith, Smith, & Malcolm, n.d.). In addition, there have also been EDMs developed for the winegrapes and wine industry (e.g. Zhao, Anderson, & Wittwer, 2002).

However, applications of EDMs have been lacking for the grains industry due to various difficulties. The grain supply chain has multiple stages and end uses: production, on and off-farm storage, secondary processing and distribution to domestic and export markets. The relationships of different grains in crop rotations and in competing end uses, as well as numerous alternative supply chains across the three different production regions, add scale and complexity to the challenges of constructing a grains industry EDM. Furthermore, previous empirical studies show evidence of imperfectly competitive market structures for grains that have implications for evaluating the distribution of benefits (see Griffith, 2000; O'Donnell, Griffith, Nightingale & Piggott, 2004), although those studies are now quite dated.

The contributions of this study are as follows. Firstly, it bridges a gap in existing literature by providing an EDM system for the Australian grains industry, the only major agricultural industry in Australia lacking such a tool at a comprehensive scale. Secondly, by constructing separate EDMs for each grain-growing region, differences in commodity type and distribution paths are captured allowing for evaluation of RD&E investments at both the aggregate national level as well as the regional level. This is particularly useful for examining the impacts of individual investments in RD&E for a commodity type in a specific region.

1.5 Outline of the Thesis

This thesis proceeds as follows: Chapter 2 provides a literature review. This includes a review of the industry context and challenges, and a discussion on the significance of agricultural research and its importance in facilitating agricultural productivity growth. A review of the various methods of evaluating the economic impacts from agricultural research is also provided. Then follows a review and discussion of the EDM approach, detailing its strengths over other evaluation methodologies.

Chapter 3 provides an overview of the Australian grains industry. This includes a review of the major grain commodities produced, including crop rotations as well as their major export markets for each crop. As the architecture of EDMs is rooted in the concept of supply and value chains, a section in this chapter provides a discussion on this concept from an agricultural perspective. Finally, the policy environment of the Australian grain industry is compared and contrasted with other countries.

In Chapter 4, conceptual issues around modelling the grains industry using an EDM framework are discussed. A review of industry data and information is also provided to help guide the specification of the equilibrium prices and quantities used to calibrate the EDM system.

Chapter 5 specifies the EDMs of the western, southern and northern regions of Australia, as specified by the GRDC. The schematic representation of each regional EDM is presented in these chapters along with a description of how the regional industries are horizontally and vertically disaggregated. In its totality, the EDM system contains 264 equations with 69 exogenous shifter variables. For each regional EDM, the equations are first represented in general form before being totally differentiated to equilibrium displacement form with integrability conditions also applied. The static nature of an EDM and its treatment of relevant dynamics that affect adjustment towards equilibrium is also discussed. Chapter 6 calibrates the initial equilibrium in all three EDMs by specifying the base quantities and prices, market parameters and exogenous shifts.

In Chapter 7, the simulation results from 8 hypothetical RD&E investment scenarios for each region are presented and are compared with one another. Both the annual returns, as well as the distribution of the returns to the various industry sectors, are reported, with the results being measured by changes in the economic surplus. Then follows further discussion and general comments about the results in Chapter 8, including a summary of key findings.

In Chapter 9, the effect of uncertainty about the value of market parameters on the base simulation results are examined through applying stochastic sensitivity analysis. This allows for the economic surplus results to be represented by probability distributions along with confidence intervals.

Chapter 10 provides a summary and conclusion to this study. Limitations to the research are discussed and future areas of research are proposed.

Chapter 2 Literature Review

2.1 Introduction

This chapter provides a brief review of literature surrounding agricultural RD&E, its relevance and importance in the grains industry, along with the various methods used in evaluating the benefits it brings.

Section 2.2 outlines a high level context and challenges of the Australian grains industry. Section 2.3 discusses the benefits and gains arising from agricultural RD&E. Section 2.4 provides an overview of the agricultural RD&E funding arrangements in Australia. Section 2.5 briefly outlines the need for evaluating investments in RD&E for priority setting, followed by Section 2.6, which provides a review of the various methods used in agricultural research and evaluation. Finally, Section 2.7 focuses on providing a detailed review of the EDM approach, detailing its strength over other evaluation methods.

2.2 Context and Challenges of the Australian Grains Industry

The Australian grains industry has grown markedly over the past 30 years, a result of changing markets and an annual growth in total factor productivity of 1.5 per cent per annum (Boult & Chancellor, 2019). The industry, however, has many challenges. Since the 1990s the rate of annual growth in total factor productivity in grain production has declined to 0.9 per cent per annum over the period 1993-94 to 2007-08 (Primary Industries Standing Committee, 2011). This slowing of growth in productivity is attributed to the adverse impacts of a warming climate and more frequent extreme weather events, a decline in expenditure on RD&E, and a slower adoption of new technologies (Hockman *et al.*, 2017; Primary Industries Standing Committee, 2011). However, since the late 2000s, the rate of annual growth in total factor productivity in grain production has recovered, especially due to more favourable seasons and the advent of new higher-yielding varieties (Boult & Chancellor, 2019; Trainor *et al.*, 2018).

Increases in the capacity of the agricultural sector to increase output comes from new technology and changes to farm systems. Investing in agricultural RD&E plays a significant role in increasing agricultural productivity (VAGO, 2016).

Allocating limited funds to grains RD&E poses challenges and trade-offs. The Grains Industry National Research, Development and Extension Strategy (Research and Innovation Committee, 2017, p.30) noted that ‘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’. Governments and research organizations need to know and demonstrate the economic impacts of research programs, to justify investments and prioritise future research. Evaluating the merits of research investment involves estimating the total benefits from the research as well as the sectoral distribution of these benefits. Economic modelling is one way to estimate the size and distribution of these net benefits of agricultural RD&E.

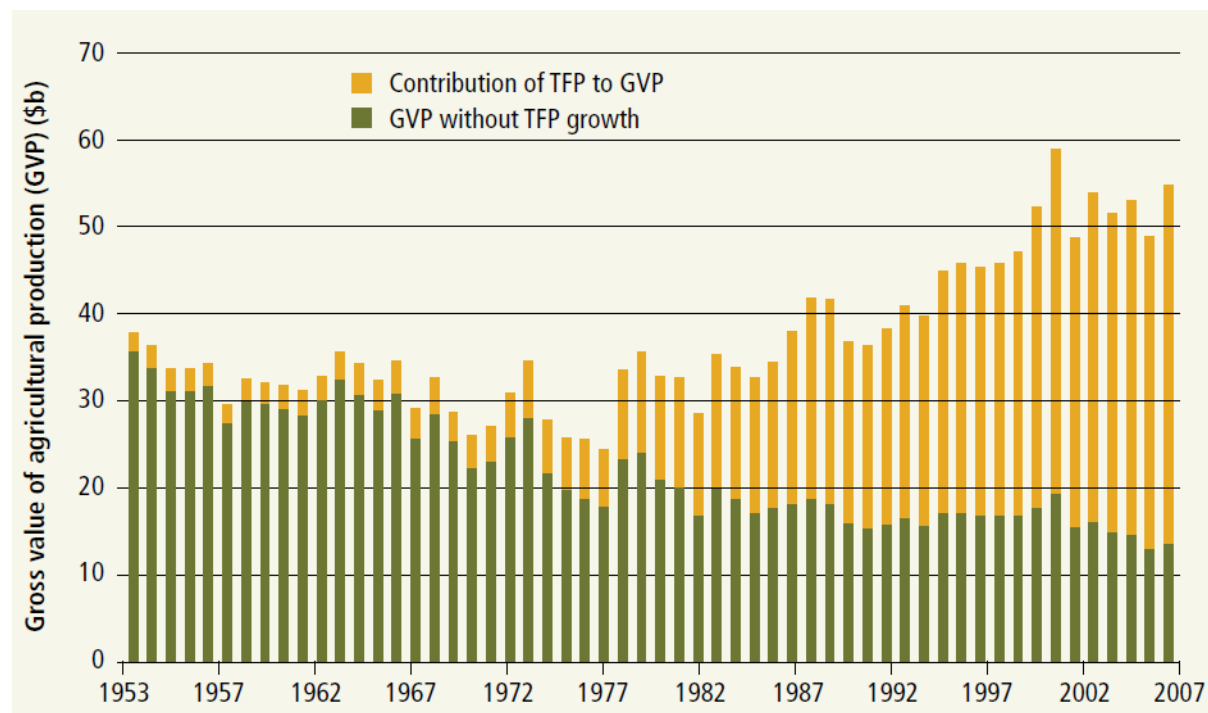
2.3 Gains from Agricultural Research, Development and Extension

Agricultural productivity is measured as the ratio of agricultural outputs to agricultural inputs. 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 (cost savings).

One of the key drivers of productivity stem from the benefits of research-induced knowledge. More specifically, Alston *et al.* (1998) pointed out that agricultural research is an investment in the production of knowledge, which can lead to:

- more output (for a given expenditure on inputs);
- cost savings (for a given quantity on inputs);
- new and better products; and
- better organisation and quicker response to changing circumstances.

Figure 2.1 depicts the positive impact that advances in total factor productivity (TFP) has on agriculture’s gross value of production (GVP).

Figure 2.1 Impact of Productivity Growth on Real Gross Value of Production

Source: Mullen and Crean (2007) (taken from Grains Industry National RD&E Strategy, 2011)

Total factor productivity growth has varied across the cropping regions over the last decades, driven by structural and climatic differences (Boult *et al.*, 2018). As shown in Table 2.1, over the period 1977-78 to 2017-18, the southern region experienced the strongest total factor productivity growth at 1.9 per cent per annum. The northern and western regions on the other hand both recorded lesser growth rates of 1.4 and 1.3 per cent per annum respectively.

Table 2.1 Total factor productivity, output and input growth, by GRDC cropping region, 1977-78 to 2017-18

Region	TFP (%)	Output (%)	Input (%)
Northern	1.4	1.9	0.5
Southern	1.9	2.8	0.8
Western	1.3	3.6	2.3

Source: Boult & Chancellor (2019)

The Productivity Commission (2011) asserts that in addition to higher productivity and competitiveness, agricultural research and development can deliver a wide range of other benefits. For instance:

- enhanced supply chain knowledge, management and efficiency;
- reduced impact from pests and disease;
- better standards of living (through cheaper food and higher quality food); and
- better environmental and social outcomes.

2.4 RD&E Funding Arrangements in Australia

There are several sources of agricultural RD&E funding in Australia.. As shown in Table 2.2, funding for rural RD&E and related activity was around \$1.5 billion nationally in 2008-09, with around three-quarters provided by Australian and State Territory Governments (Productivity Commission, 2011).

Most Australian Federal Government's funding for agricultural RD&E is provided to Rural Research and Development (RDCs). Each RDC is responsible for the planning, investment and oversight of RD&E for a major industry in the agricultural sector. The Grains Research and Development Corporation (GRDC) serves as the RDC for Australia's grains industry. There are currently 15 RDCs comprising five Commonwealth statutory bodies (including the GRDC) and 10 industry-owned companies (IOCs). Each RDC obtains its funding through industry levies collected from primary producers and matching contributions from the Australian Government on a dollar-for-dollar basis, generally up to 0.5 per cent of the determined industry gross value of production. Under these arrangements, the RDC model provides a unique system for Government and primary producers alike to co-invest in agricultural RD&E. As can be seen in Table 2.2, around \$248 million of levies to RDCs were collected from primary producers, with the Australian government contributing around \$218 million. Combined together, these two sources contributed to over 30% of total agricultural RD&E funding during this period.

Table 2.2 Source of Agricultural RD&E Funding in Australia, 2008-09

<i>Organisation type</i>	<i>Funding</i>	<i>Share</i>
	million	%
Australian Federal Government		
Cooperative Research Centres	63	
Core funding for the CSIRO	193	
Core funding for the universities	118	
Research and Development Corporations (RDCs)	218	
Other departmental Programs	114	
Forgone tax receipts arising from RD&E tax concessions	9	
<i>Total Australian Government</i>	715	48
State and Territory Governments	348	
Project-related budget allocations	47	
Capital investment in RD&E facilities	21	
Payments to other funders and suppliers	416	
<i>Total State and Territory Governments</i>		28
Private/Industry		
Levy payments provided to RDCs	248	
Other (for which a tax concessions is claimed)	116	
<i>Total Private/Industry</i>	364	24
Total	1495	100

Source: Productivity Commission Inquiry Report – Rural Research Development Corporations (2011).

Table 2.3 provides a more detailed breakdown of RDC funding in 2014-15. Levy contributions to the GRDC are far larger than levy receipts of any other RDC, with over \$117 million collected from growers, representing around 40% of total levy contributions to all RDCs (Millist *et al.*, 2017).

Including contributions from the Government, an estimated \$185 million of funding was allocated to the GRDC in 2014-15, representing around 20% of the funding across all RDCs.

Table 2.3 Breakdown of funding generated by Rural Research Corporations, 2014-15

RDC	Government matching (\$m)	Levy contributions (\$m)	Voluntary industry contribution (\$m)
Australian Grape and Wine Authority	12.35	11.85	–
Cotton Research and Development Corporation	7.30	7.3	–
Fisheries Research and Development Corporation	18.71	7.16	0.21
Grains Research and Development Corporation	67.85	117.59	–
Rural Industries Research and Development Corporation	12.74	4.48	–
Australian Egg Corporation Ltd	1.78	2.03	–
Meat and Livestock Australia Ltd	42.26	28.53	26.80
Australian Livestock Export Corporation Ltd (LiveCorp)	–	0.94	–
Australian Meat Processor Corporation Ltd	–	14.21	–
Australian Pork Limited Ltd	5.19	5.18	–
Australian Wool Innovation Ltd	12.48	19.36	–
Dairy Australia Ltd	21.39	25.81	–
Forest and Wood Products Australia Ltd	3.30	2.59	–
Horticulture Innovation Australia Ltd	41.02	26.32	16.80
Sugar Research Australia Ltd	6.06	22.68	–
Total	252.72	296.02	43.81

Source: Millist *et al.*, (2017)

Table 2.4 below provides a breakdown of the proportion of GRDC's RD&E expenditure against broad R&D priority areas. The GRDC invests the majority of its funding on research targeting, productivity and adding value. This includes improving the productivity and profitability of existing industries and supporting the development of new industries.

Table 2.4 Proportion of RD&E expenditure by GRDC against R&D priorities, 2014-15

Productivity and adding value	55%
Supply chain and markets	5%
Natural resource management	8%
Climate	3%
Biosecurity	18%
Innovation Skills	10%
Technology	0%
Other	1%
Total	100%

Source: Millist *et al.* (2017)

2.5 The Need for Agricultural Research Evaluation

Agricultural research can be viewed as an investment in the production of knowledge or information, and like any type of investment, it involves the expenditure of scarce resources or funding at the cost of other alternative forgone consumption or investment choices (Alston *et al.*, 1998). Governments and funding agencies are required to allocate monies for research projects, yet face budget limitations. Consequently, not all research problems can be investigated due to scarcity in research resources, including finance, skilled labour and other inputs (Alston *et al.*, 1998). As fiscal conditions tighten, agricultural research evaluation and priority setting increasingly become important. Hence, there is a need from an accountability point of view to measure the economic impacts of agricultural research in order to improve decision making and effective management of public funds.

2.6 Evaluation of Economic Impacts in Agricultural Research

Alston *et al.* (1998) outline that agricultural research is an economic activity involving the investment of scarce resources in the production of knowledge. History reveals how agricultural RD&E, as applied to the grains industry, has led to advances in most aspects of planting, growing and harvesting crops, and processing crop products. Many advances are incremental improvements whilst a few are disruptive innovations borne of breakthrough scientific studies (Sunding and Zilberman, 2001).

The economic and social importance of agricultural RD&E has been a topic of interest for many decades as evidenced by the large number of studies that examine payoffs to agricultural RD&E. Difficulties however, have always arisen in precisely quantifying the overall net benefit between producers and other participants in the value chain.

As noted by Borrell *et al.* (2014), estimates of the size and distribution of net benefits of a change in productivity resulting from investing in RD&E depend on:

- (i) the type and nature of the change caused by successful RD&E;
- (ii) where the change occurs in the supply chain;
- (iii) the price elasticities of supply and demand and substitution between inputs and substitution between final products; and
- (iv) the relative sizes of the gross value of production at each point along the value chain.

The large body of literature dealing with the evaluation of agricultural research primarily covers two major methodologies – *Economic Surplus Methods* and *Econometric Measurements*.

2.6.1 Economic Surplus Methods

The most popular and successful approach used to assess the impacts of investments in agricultural research is the economic surplus approach (Alston *et al.*, 1998). This approach evaluates the benefits from shifts in supply due to changes in productivity (i.e. brought about by an introduction of agricultural innovation). Changes in productivity will affect the relationship between inputs and outputs and this will in turn, change the relationship between production costs and output and thus between supply and price. Using this approach, the technological impacts spurred from research can be assessed by looking at the relationship between research investments and a commodity's industry-level supply function.

The basic model (in a closed economy) for the economic surplus measure, as described by Alston *et al.* (1998), is illustrated in Figure 2.2. S_0 is the supply curve under original technology, and S_1 is the supply curve after research-induced technical change. The initial equilibrium price and quantity are P_0 and Q_0 , and the new equilibrium price and quantity after the supply shift are given by P_1 and Q_1 .

The total benefit and change in consumer surplus from the research induced supply shift is given by the area I_0abI_1 . This net benefit can be decomposed into two parts – (1) the cost saving on the original quantity (the area I_0acI_1) and (2) the economic surplus due to the increment to production and consumption (area abc). Alternatively, the total benefit can also be broken down into the change in both consumer surplus ($\Delta CS = P_0abP_1$), and producer surplus ($\Delta PS = P_1bI_1 - P_0aI_0$). Mathematically, these effects can be expressed as follows:

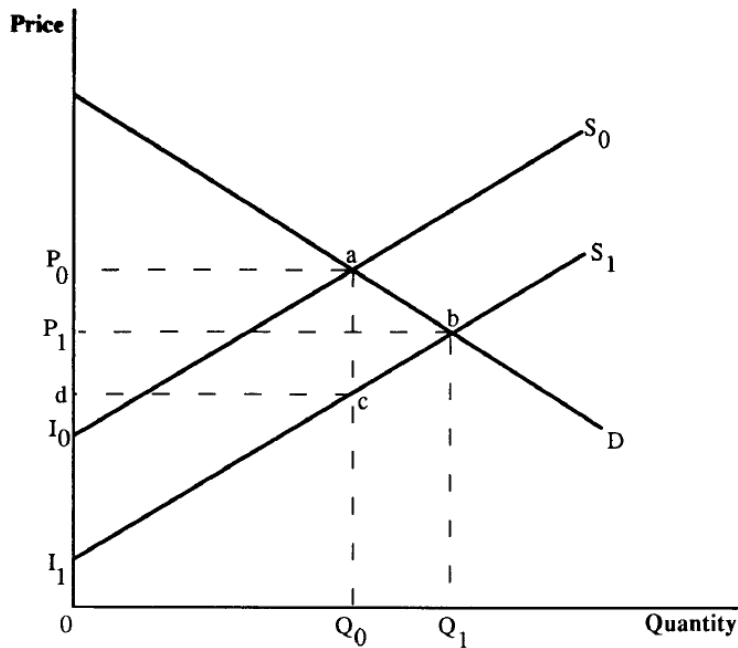
$$\Delta CS = P_0 Q_0 Z (1 + 0.5 Z \eta) \quad (2.5.1)$$

$$\Delta PS = P_0 Q_0 (K - Z) (1 + 0.5 Z \eta) \quad (2.5.2)$$

$$\Delta TS = \Delta CS + \Delta PS = P_0 Q_0 K (1 + 0.5 Z \eta) \quad (2.5.3)$$

where K (also known as the K -factor) is a (research induced) shift of the supply function expressed as a proportion of the initial price, η is absolute value of price elasticity of demand, ϵ is the elasticity of supply, and $Z = K \epsilon / (\epsilon + \eta)$ is the proportional price reduction in the market relative to the initial base case (pre-research) scenario. The economic surplus formulae represented in equations (2.5.1), (2.5.2) and (2.5.3) are widely used in economic evaluations of agricultural research.

Figure 2.2 Consumer and Producer Surplus Measurement



Source: Alston (1991)

Policy makers have an interest in knowing not only the size of the economic benefits associated with research investment, but also its distribution among different industry groups. As such, the basic model in Figure 2.2 is often extended to consider various multimarket settings. As stated by Alston (1991), this firstly includes disaggregating the total benefits to answer questions relating to the distribution of benefits among stages in a multistage production system (vertical incidence), e.g. at the farm level (upstream), retail level (downstream), and some intermediate stage such as the marketing system. The measurement of the total benefits (consumer surplus plus producer surplus) will not be affected by the choice of where to measure benefits in the supply chain as it will be the same at all levels. The only thing affected by the choice of measurement perspective is the distribution of consumer surplus versus producer surplus. Secondly, the distribution of benefits can also be examined across different markets for the same product in different places or for different products (horizontal incidence). For example, at a given market level, supplier and demanders can be disaggregated into subcategories according to geopolitical boundaries (e.g. domestic and foreign/export) or according to other characteristics (Alston, 1991).

Many studies have examined the returns on agricultural investments using economic surplus approaches. Griliches (1958) provided one of the earliest examples of applying economic surplus concepts to *ex post* evaluation of agricultural research. Griliches focused on a successful agricultural venture – the introduction of hybrid corn in the USA, examining both the total research and development expenditures that led to its creation as well as the subsequent net increase in the value of the corn crop from 1910 to 1955. The analysis provided strong evidence for the gains from RD&E, with the net social returns estimated to be at least 700 per cent per year.

Other early examples of economic surplus approaches to *ex post* agricultural evaluation include Peterson (1967) and Schmitz and Seckler (1970). Peterson's work focused on the returns to poultry research in the USA, estimating that past investments in poultry research had yielded returns of around 20 to 30 per cent per year. Schmitz and Seckler, on the other hand, studied the impacts of mechanised agriculture on social welfare, focusing on the development of the tomato harvester. They tested the impacts under two cost saving scenarios, taking into consideration both the displacement effects the new innovation had on tomato workers and as well as the amount of compensation needed to offset the impact of technological change for displaced workers (based on the Kaldor-Hicks criterion). Under the low cost saving scenario, the net social rate of return varied between 929 and -8 per cent, whilst under the high cost saving scenario, the net social rate of return varied between 1,288 and 345 per cent.

Many *ex ante* studies of agricultural research priorities have also used the economic surplus approach. Davis *et al.* (1987) developed a multi-regional international trade model to derive *ex ante* measures of the relative economic benefits of alternative commodity and regional research portfolios, as well as the distribution of these benefits among consumers, producers, importers and exporters. Norton *et al.* (1987) examined the benefits of agricultural research and extension using a consumer surplus framework for five commodities. In their study, particular attention was given to the effects of demand shifts over time and government pricing policies on RD&E benefits.

The effects of research-induced technological benefits may not simply be limited to just the consumers and producers of the commodity directly affected by the technological changes, but also the consumers and producers of other related commodities through cross-commodity feedback effects (Alston *et al.*, 1998). For instance, an improvement in technology in the pork meat industry initially shifts the supply of pork downwards and reduces its price. This may also, however, cause a reduction in the demand of beef (and a reduction in its price) if pork and beef are substitutes. This may be complicated further if the reduction in the price of beef causes additional feedback to the pork market (and changes the final equilibrium price and quantity in this market). These complementary feedback effects were first demonstrated in Buse's (1958) paper, where the concept of a 'total elasticity' was first introduced. The total elasticity for demand and supply in an industry captures the total price sensitivity of a good in response to its own-price changes as well as feedback effects from price changes in related goods. This may be particularly relevant for the grains industry considering that the crops produced in a crop rotation system are 'joint products', that is, outputs generated simultaneously using common inputs. This means that technical change that affects one crop (e.g. lupins) may also affect another crop in the cropping sequence (e.g. barley) through its effects on soil structure, fertility, pest and diseases, and through substitution in consumption (Alston, 1995).

2.6.2 Cost Benefit Analysis

Cost benefit analysis is a closely related variation to economic surplus methods. It is a versatile method of evaluation that estimates the value of investments to determine whether those investments are worth undertaking, and can be applied to many different types of investment projects, not just research investments (Heisey *et al.*, 2010). As discussed in the study by Alston *et al.* (1998), in cost-benefit analysis, a stream of annual research benefits captured by producer and consumer surpluses are discounted and distributed over time; internal rates of return, net present

values, and benefit-cost ratios are then applied to capture the time value of money and determine the net benefit to society. Their study notes that in many applications, cost-benefit analysis assumes either explicitly or implicitly that:

- (i) extra production is calculated at a single fixed market price, and is captured an outward shift of a vertical (perfectly-inelastic) supply curve against a horizontal (perfectly-elastic) demand curve, or
- (ii) the value of inputs saved are calculated at a fixed level of production, and are captured by a downward shift of a horizontal supply curve against a vertical demand curve.

Their study highlighted that the advantage of employing this type of approach is that it eliminates the need to obtain elasticity estimates, with the disadvantages being that it ignores regional and international price effects due to the research, and distributional effects are ignored.

2.6.3 Econometric and Statistical Methods

Econometric models have been used to estimate the relationship between past investments in agricultural RD&E and agricultural production and productivity. The ability of econometric models to account for a variety of changes simultaneously makes them highly useful (Heisey *et al.*, 2010). In addition, econometric estimation can allow for dynamic relationships such as seasonality and time effects to be captured within the model, and can also allow researchers to statistically test hypotheses about the parameters (Ludlow, 2013; Mounter *et al.*, 2008). This is especially relevant from an agricultural perspective given that seasonality conditions influence the yields of crops and other products (Griffith *et al.*, n.d.).

Econometric models include both *parametric* and *non-parametric* approaches. Parametric approaches involve specifying an explicit functional form that links inputs to outputs (Alston *et al.*, 1998). This can include direct estimation of production functions, which model agricultural output quantities as a function of inputs; response functions, which model the factors that influence an important variable such as crop yield; or productivity functions, which estimate output per unit of input (Heisey *et al.*, 2010).

Conventional approaches to modelling production involve estimating a parametric model and evaluating the properties of the estimated model. For example, as presented and explained by Alston *et al.* (1998), an econometric approach can be used to estimate an agricultural production

function, which is the most common econometric method used to estimate the economic benefits of agricultural research:

$$Q_t = q(X_t, W_t, H_t, P_t, Z_t, R_{t-r}, E_{t-e}) \quad (2.5.4)$$

Where $q(.)$ is a production function that link inputs to agricultural output in time t , Q_t .

The set of inputs in equation (2.5.4) include:

X_t – a vector of conventional inputs

W_t – uncontrolled factors such as weather in this instance

Z_t – various infrastructural variables (such as public investment in roads, communications, irrigation and education)

H_t – stock of human capital in agriculture

P_t – relative factor prices

R_{t-r} – past (lagged) investments in research

E_{t-e} – past (lagged) expenditure in extension services

By estimating the equation 2.5.4, one can then determine the economic benefits from research by calculating the value of the additional output attributable to the lagged research expenditures (holding other inputs constant) or the value of the savings in inputs due to the lagged research expenditures (holding output constant). Lagged values for research investment and expenditure in extension services are used because research does not affect agricultural production directly or instantaneously, that is, there is usually a considerable a lag before usable technologies can be generated from research investments (Alston *et al.*, 1998).

An obvious drawback of the parametric approach is that different results are be obtained, depending on the functional form $q(.)$ chosen for the model. Non-parametric approaches are an alternative way to assess the effects of past agricultural research investments. Non-parametric approaches completely avoid the use of functional forms. This indirect approach involves treating the sector being analysed as a firm, using models of firm and producer behaviour to incorporate changes in economic data (Heisey *et al.*, 2010).

2.7 Equilibrium Displacement Modelling

Economic surplus approaches are the most widely used approach to assess the impacts of agricultural investments. These approaches have the advantage of being versatile in analysing particular rather than aggregate effects of research. These approaches are also non-data intensive (Masters, 1996).

To estimate an economic surplus, researchers must first decide on a modelling strategy. This involves decisions on the type of functions (e.g. linear vs. non-linear) and the type of supply and demand shift (e.g. parallel vs pivotal) (Ludlow *et al.*, 2013). The modelling strategy and scope of the study will also define the data requirements (Alston *et al.*, 1998). Researchers must then choose from various different techniques when measuring economic surplus. Econometric techniques are one possibility, whereby time series data on the variables in the model are used to estimate parameter values. This subsequently enables the estimated equations in the model to predict changes in prices and quantities, and hence can measure economic surplus. Although potent in their abilities, econometric models are data-intensive. As pointed out by Mounter *et al.* (2008), the data-intensive nature of econometric models makes them difficult to maintain and update in cases when data gets collected and publically reported infrequently.

Equilibrium Displacement Models (EDMs) are a popular economic surplus approach due to their strong theoretical basis and non-data intensive requirements. They do not require extensive time series data, and only require base equilibrium price and quantity data for a representative or average year along with estimated Marshallian elasticity values taken from published work or expert opinion (Vere *et al.*, 2005). First coined by Piggott (1992), EDMs are a distinctive kind of comparative static approach that expresses the system of equations in the model in elasticity form. One advantage of its construct is that it enables researchers to use information on partial elasticities, quantity, and expenditure shares in order to calculate the importance of various supply and demand shift parameters on market outcomes (Wohlgenant, 2011). Although, an inherent limitation to this is the necessity in choosing accurate parameter values when calibrating the model. This however, can be addressed through stochastic sensitivity analysis.

As mentioned in section 2.6.3, one of the drawbacks of parametric approaches in econometric modelling is that it requires a functional form to be specified. An EDM does not, since the systems of equations are expressed in terms of relative changes/elasticities, and are hence linear in nature.

Estimates obtained this way can yield good approximations for small shifts in the equilibrium. The next sub-section is a review of some important concepts for EDMs.

2.7.1 Review of EDM Concepts

An EDM portrays a particular market situation characterised by a set of supply and demand equations – consistent with economic surplus methods described previously. No functional forms are assumed for these equations. The market is then ‘shocked’ by a change in the value of an exogenous variable in the system. The impacts of the shock or disturbance are then approximated by functions linear in elasticity. An EDM differs from other comparative static approaches as it is underpinned by the concept of elasticity; changes in endogenous and exogenous variables are measured in proportionate terms or as ratios of proportionate changes (i.e. elasticities).

The EDM approach is sometimes also known as ‘Muth modelling’, in reference to the significant paper by Muth (1964) who first demonstrated its use. The modified version of Muth’s (1964) model by Alston *et al.* (1998) is shown below. Here, the market is characterised by a competitive industry producing a single homogeneous product using two factors of production. Following the notation used in both Alston *et al.* (1998) and Muth (1964), the equations characterising the market are:

$$\text{Consumer demand: } Q = f(P) \quad (2.6.1)$$

$$\text{Production: } Q = q(X_1, X_2) \quad (2.6.2)$$

$$\text{Factor demand: } W_1 = Pq_1 \quad (2.6.3)$$

$$W_2 = Pq_2 \quad (2.6.4)$$

$$\text{Factor supply: } X_1 = g(W_1) \quad (2.6.5)$$

$$X_2 = h(W_2) \quad (2.6.6)$$

Where Q is the quantity of product, P is the Price of product, X_1 and X_2 are the quantities of factors 1 and 2, W_1 and W_2 are the factor prices of factors 1 and 2, and q_1 and q_2 are the marginal products of factors 1 and 2 respectively ($q_i = dq(\cdot)/dX_i$ for factor i).

Equation 2.6.1 shows the demand for the industry’s output, equation 2.6.2 is the production function, equations 2.6.3 and 2.6.4 are factor demand equations with each factor being paid at the

value of its marginal product, and equations 2.6.5 and 2.6.6 are the factor supply equations. Constant returns to scale are assumed at the industry level.

Equations 2.6.1 to 2.6.6 are then differentiated, converting them to elasticity form and also adding exogenous shocks to yield the following equations expressed in terms of relative changes and elasticities:

$$E(Q) = -\eta[E(P) - \alpha] \quad (2.6.1')$$

$$E(Q) = s_1 E(X_1) + s_2 E(X_2) + \delta \quad (2.6.2')$$

$$E(W_1) = E(P) - (s_2/\sigma)E(X_1) + (s_2/\sigma)E(X_2) + \delta + \gamma \quad (2.6.3')$$

$$E(W_1) = E(P) - (s_1/\sigma)E(X_1) + (s_1/\sigma)E(X_2) + \delta - (s_1/s_2)\gamma \quad (2.6.4')$$

$$E(X_1) = \varepsilon_1[E(W_1) + \beta_1] \quad (2.6.5')$$

$$E(X_2) = \varepsilon_2[E(W_2) + \beta_2] \quad (2.6.6')$$

Where E denotes relative changes (e.g., $E(Q) = \Delta Q/Q \cong \Delta \log(Q)$), η is the absolute value of the elasticity of demand, α is a vertical shift in the demand function reflecting an increase in demand, s_i is the cost share of factor i ($s_i = W_i X_i / PQ$), σ is the elasticity of substitution between X_1 and X_2 , ε_i is the elasticity of supply of factor i , and β_i is a vertical shift down in the supply of factor i reflecting an increase in its supply.

α , β_1 , β_2 , δ , and γ are exogenous shift parameters, expressing equilibrium displacements relative to an initial equilibrium.

As can be seen, equations 2.6.1' to 2.6.6' do not have any assumptions concerning functional forms of supply and demand; as EDMs are a local approximation to unknown functions (Alston *et al.*, 1998). The size and total distribution of total benefits from research can then be approximated as follows:

$$\Delta CS = -P_0 Q_0 (EP - \alpha)(1 + 0.5EQ) \quad (2.6.7)$$

$$\Delta PS_i = W_i X_i (EW_i - \beta_i)(1 + 0.5EX_i) \quad (2.6.8)$$

$$\Delta TS_i = \Delta CS + \sum_i \Delta PS_i \quad (2.6.9)$$

For $i=1,2$ (each factor of production)

2.7.2 Dynamics

EDMs are a form of comparative static analysis comparing two different equilibrium states, before and after a change in an underlying exogenous parameter (representing the impacts of new innovations and technologies) in the model. An EDM does not consider the dynamic path of adjustment towards equilibrium, nor the process of change itself.

In reality, there is a time dimension involved in the research investment cycle. As mentioned in section 2.6.3, research does not affect agricultural production directly or instantaneously, in that there is usually a considerable amount of time elapses before usable technologies can be generated from research investments. Furthermore, as with any other form of capital, the knowledge generated through agricultural research becomes obsolete or depreciates over time. Therefore, time lags exist between the commencement of research, full adoption and eventual disadoption of a new innovation or technology. A limitation of EDMs is that they do not account for these dynamic responses within the framework. Exogenous shifts in the model representing the impacts of new technologies or promotions are assumed to be instantaneous and the benefits are indicative of the returns assuming full adoption and complete market adjustment (Mounter *et al.*, 2008, p.80).

An implication of incorporating dynamics in the analysis is that the elasticities of demand (η) and supply (denoted by η and σ respectively in Chapter 6) can no longer be treated as constants and will change and become more elastic over the adjustment process. This is because the more time a consumer and producer has to respond to price changes, the more elastic their demand and supply curves will be. Piggott (1992) highlighted that this could be remedied to some extent by repeated applications of EDM using elasticities corresponding to different lengths of run.

As stated in Section 2.6.1, the K factor represents the size of the research induced supply shift. In a dynamic setting, the K factor will vary over time (i.e. K_t), as typically the flow of benefits begins once the adoption phase commences and gradually increases over time until full adoption. As such, the K factor becomes the most crucial variable in system, as different approaches for estimating K_t can yield significantly different results (Alston *et al.*, 1998; Norton, 2015). Various approaches for estimating K_t include (i) the use of expert opinions of scientists and other research experts, (ii) incorporation of input and yield data from biological field experiments in budgets combined with adoption data from surveys, (iii) use of survey data at the farm-household or plot level in regression-based analyses, and (iv) randomised controlled trials. Just *et al.* (1982), as cited in Zhao *et al.* (2000),

presented an approach to measuring the welfare impacts for the years after the initial exogenous shock and before reaching the new equilibrium, using different supply curves of different lengths of run.

2.7.3 Applications of Equilibrium Displacement Modelling in Various Agricultural Industries to Facilitate RD&E Decisions

EDMs have been used extensively to determine the impacts of new policies in many agricultural settings in Australia. This has been especially prevalent in the Australian livestock sector, with EDMs having been developed for a number of industries such as the beef industry (Zhao *et al.*, 2000), the sheep and wool industry (Mounter *et al.*, 2008), pig industry (Mounter *et al.*, 2004), and the dairy industry (Liu *et al.*, 2012; Ludemann *et al.*, n.d.). In addition, there have been EDMs developed for the winegrapes and wine industry (e.g. Zhao *et al.*, 2002). Here we briefly review the two EDMs developed in the beef and sheep and wool industries.

The EDM developed by Zhao *et al.* (2000) was used to (1) estimate and compare the potential benefits from research induced new technologies, generic promotion investments, and other policy changes in different sectors and markets of the Australian beef industry, and to (2) estimate the distribution of the economic impacts among different industry participants such as farmers, feedlotters, processors, exporters, retailers and domestic and overseas consumers. Vertically, the model was disaggregated to include the multi-stages of beef production and marketing, whilst horizontally, the model was disaggregated to include grain and grass finishing streams and domestic and export markets. The model was then used to analyse the effects of 12 hypothetical investment scenarios. These scenarios were modelled as 1 per cent exogenous parallel shifts in their relevant market demand or supply curves. It was found that domestic grassfed beef promotion and domestic beef marketing technology resulted in the largest total returns of \$31.55 m and \$23.88 m respectively (Zhao *et al.*, 2000, p.85). This was predominantly due to the large gross revenue levels (and large value added) in the domestic grassfed beef market and the domestic marketing and retailing sectors. By contrast there were small gains from research in the backgrounding, feedlot, processing and export marketing sectors due to their smaller contribution in the beef/cattle product value chain.

The model found that for all 12 scenarios, the majority of total benefits accrued to domestic consumers and cattle farmers, with domestic consumers gaining the largest share of total benefits (between 48.3% to 65.6%) and farmers gaining between 19.8% to 33.7% of total benefits in all 12

scenarios (Zhao *et al.*, 2000, p.85). Overseas consumers and domestic retailers also gained significant shares of the gains from research, with the shares of total surplus gains going to overseas consumers ranging between 5.1% to 11.7%, whilst domestic retailers gained between 3.6% to 6.8% of total benefits in all scenarios (Zhao *et al.*, 2000, p.86).

Similarly, the EDM developed by Mounter *et al.* (2008) also estimated and compared the potential benefits from new technologies, generic promotion investments, and other policy changes in the different sectors and markets of the Australian sheep and wool industries. As outlined by Mounter *et al.* (2008), the model considered numerous market segments, employing a high degree of horizontal and vertical disaggregation to allow for the distribution of total industry returns among the various regions and sectors to be estimated. The sheep industry was horizontally disaggregated into Merino sheep and non-Merino sheep, and Merino sheep were further disaggregated by production enterprise in each of three agricultural zones; high rainfall, wheat-sheep and pastoral. Australian wool production was horizontally disaggregated into four main fibre diameter categories corresponding to the Australian Bureau of Statistics wool export categories of 19 μm and finer, 20-23 μm , 24-27 μm and 28 μm or broader. On the other hand, vertical disaggregation of the wool industry included the warehousing, export and Australian early-stage processing sectors, whereas vertical disaggregation of the sheepmeat supply chain consisted of the processing and marketing sectors. The EDM was importantly able to account for cross-product interactions (previously mentioned in section 2.6.1) between the Australian sheep and wool industries that were not considered in most previous EDMs of the Australian sheep and wool industries (Mounter *et al.*, 2008).

Using the model, Mounter *et al.* (2008) considered the effects of RD&E and promotion investments in two hypothetical scenarios – firstly, a reduction in the cost of producing lamb, and secondly, a hypothetical wool promotion investment in the export market. One main finding for Scenario 1 was that domestic consumers were the main beneficiaries, although the proportion of total benefits collected by overseas consumers were also sizeable. As wool and lamb are joint-products, the supply of wool also increased in correspondence to an increase in lamb production, leading to an expansion in the supply of wool exports. Sheep and wool producers on the other hand, were found to receive less than a quarter of the total benefits. In other parts of the supply chain, the domestic sheepmeat processing and retail sectors were the only sectors to exhibit moderate gains. For scenario 2, overseas consumers gained the majority share of total returns from export promotion of greasy wool, with buyers of greasy or semi-processed wool obtaining over 85 per cent of the total benefits

going abroad. Domestic consumers by contrast received a smaller share of the total benefits. Similar to scenario 1, cross-commodity effects were observed due to the joint production nature of wool and lamb – as the supply of wool increased due to promotional investments, the supply of lamb also increased.

2.8 Summary

This chapter provided a background and review of the main issues surrounding agricultural RD&E along with the various methods used for evaluation and priority setting.

The Australian grains industry has many challenges, with industry performance being heavily reliant on climate conditions. Fluctuations in growing conditions having been observed over the last few decades affecting total factor productivity. This was evident during the early 1990s and 2000s where a slowing in total factor productivity was observed, and was a large part due to frequent extreme weather events, along with a decline in expenditure on RD&E, and a slower adoption of new technologies.

Investing in agricultural RD&E can play a significant role in addressing these challenges by boosting productivity and yield. However, funding constraints exist which pose challenges towards investment decisions in RD&E and their trade-offs. Both funding agencies and producers have a vested interest in the efficient allocation of investment funds to maximise benefits and returns. Evaluating the impacts of agricultural research can provide important information about the value and impact of proposed RD&E in order to guide the allocation of limited research funds.

Various evaluation methods exist in literature, with the majority falling under two broad categories – *Economic Surplus Methods* and *Econometric Measurements*. Equilibrium Displacement Models (EDMs) are a popular economic surplus approach due to their strong theoretical basis and non-data intensive requirements.

An EDM characterises a market situation by a set of supply and demand, whereby no functional forms are assumed for these equations. The model is calibrated with base equilibrium price and quantity data for a representative or average year along with estimated Marshallian elasticity values taken from published work or expert opinion. The market is then ‘shocked’ by a change in the value

of an exogenous variable in the system. The impacts of the shock or disturbance are then approximated by functions linear in elasticity.

EDMs have been used extensively to determine the impacts of new policies in many agricultural settings in Australia, in particular, the livestock sector. Applications of EDMs have, however, been lacking for the grains industry due to conceptual and modelling complexities. Chapters 3 and 4 next provide an appreciation of the scope and conceptual challenges involved in modelling the Australian grains industry.

Chapter 3 Overview of the Australian Grains Industry

3.1 Introduction

To model the Australian grains industry, it is necessary to understand the nature and characteristics of the industry. This chapter reviews the industry in detail as follows: Section 3.2 provides an overview of the scope and features of the industry, including the various cropping regions, major grains produced, and different cropping rotations utilised. Section 3.3 discusses the major markets for key grain commodities, including their main uses and export destinations. Section 3.4 provides a brief review and comparison between the policy environments of both the Australian and overseas grains industries.

3.2 Grain Production in Australia

3.2.1 Overview

Grains are important staple food used worldwide for human consumption. They are also a source of feed for livestock and are a feedstock for biofuel production. Grains are classified into cereal grains, oilseeds and pulses (grain legumes). In Australia, grains are a major group of agricultural commodities. In 2018-19, cereal grains, oilseeds and pulses contributed an estimated \$8 billion to the Australian economy (ABARES, 2019a).

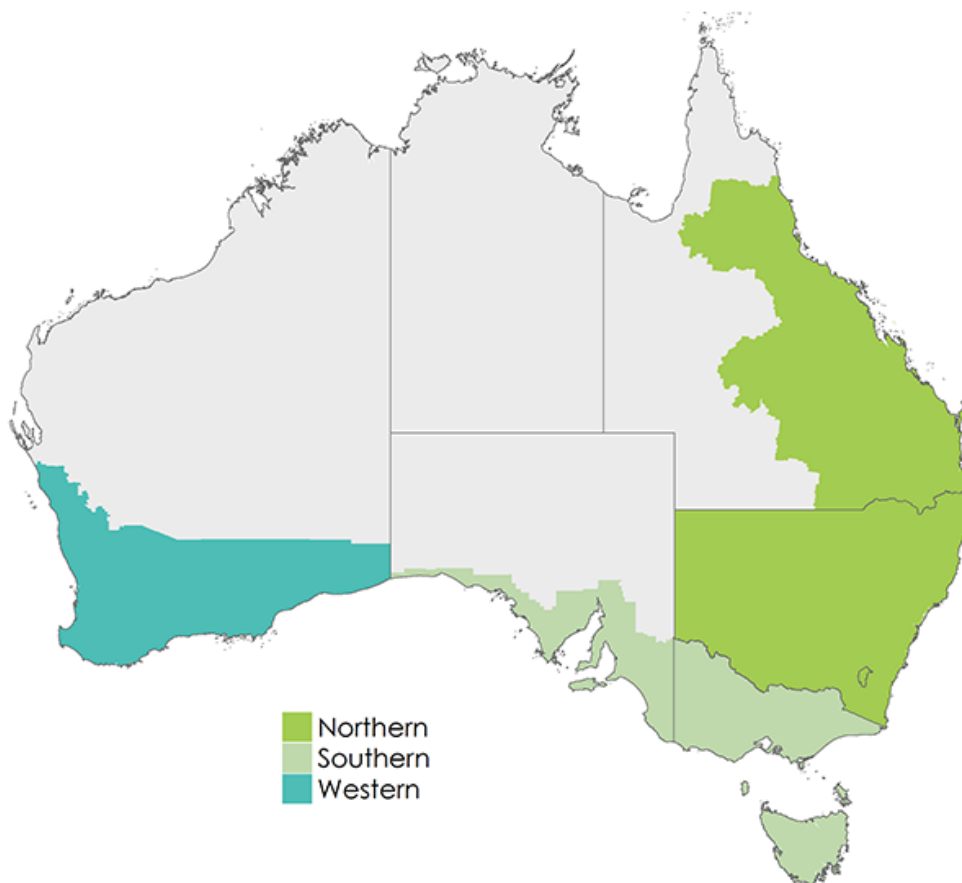
Australian grain production occurs in three main cropping regions – northern, southern, and western (see Figure 3.1), and two crop-growing periods – winter and summer (GRDC, 2018a; Australian Grain, 2013). Winter grain production vastly dominates summer grain production.

The northern cropping region is in central to southern Queensland (Qld) and New South Wales (NSW). Most of the rainfall in Qld and northern NSW occurs over the summer months, with some rainfall also occurring during winter. The rainfall patterns in central and southern NSW are generally uniform. The northern cropping region has highly fertile soils with high moisture storing capacity. Rainfall over the summer makes it feasible to grow summer crops of maize, sorghum, and tropical pulses and the winter crops of wheat, barley, winter-pulses and oilseeds.

The southern cropping region is in south-eastern Australia, including Victoria (Vic.), Tasmania (Tas.) and south-eastern South Australia (SA). This region encompasses Temperate (uniform) and Mediterranean climates. Winter and spring rainfall dominates this region. Crop yields in the southern grain producing region depend on seasonal rainfall. Soil fertility is low.

The western cropping region is in Western Australia (WA). Winter cropping is the main activity, based on winter and spring rainfall. Soil fertility is low. Wheat, barley, canola, and lupins are the main grain crops. As shown in Tables 3.1 and 3.2, over 24 million hectares of crops were planted in 2016-17 across Australia, mostly winter crops.

Figure 3.1 GRDC cropping regions



Source: Grains Research and Development Corporation

3.2.2 Wheat and Barley

The major winter cereals in Australia are wheat and barley. Wheat is the major grain crop in Australia and is used to make breads, noodles, pastas, cakes and biscuits. As shown in Table 3.1, over 12 million hectares of wheat was sown in 2016-17, producing a crop of nearly 32 million tonnes (a record 2.6 t/ha average yield). From 2014 to 2017, an annual average of 25 million tonnes of wheat was produced in Australia. WA has the highest production of wheat compared to other States, accounting for over one-third of the nation's wheat production. Production of wheat in each State is shown in Table 3.2.

Table 3.1 Australian winter crop production and area, 2014/15-2016/17

Crop	Area			Production		
	2014–15	2015–16	2016-17	2014–15	2015–16	2016-17
	'000 ha	'000 ha	'000 ha	kt	kt	kt
Wheat	12,155	11,282	12,191	23,076	22,275	31,819
Barley	3,912	4,108	4,834	8,173	8,992	13,506
Canola	2,824	2,091	2,681	3,447	2,775	4,313
Chickpeas	425	677	1,069	555	875	2,004
Faba beans	164	220	233	284	301	484
Field peas	237	238	230	290	205	415
Lentils	189	225	276	242	182	680
Lupins	443	534	515	549	652	1,031
Oats	869	821	1,028	1,184	1,300	2,266
Triticale	126	78	62	225	127	150

Source: Australian crop report, ABARES; Australian Bureau of Statistics; Pulse Australia

Table 3.2 Australian wheat production by State, average 2014-2017

State	Production ('000 tonnes)
Western Australia	9,078
New South Wales	7,317
South Australia	4,287
Victoria	3,096
Queensland	1,380
Tasmania	37
Total	25,195

Source: AEGIC (2018a)

Yields of wheat vary greatly each year from region to region due to variable rainfall (ABS, 2006). By illustration, the average yield across Australia was 0.77 tonnes per hectare in the widespread drought of 1982-83, and 2.11 tonnes per hectare in 2016 when exceptionally good widespread seasonal conditions prevailed.

Australia produces around 3 per cent of the world's wheat. It is a major wheat exporter, exporting to more than 40 countries and in years when seasonal conditions are good, Australia accounts for 10-15 per cent of annual global wheat exports (ABS, 2006; AEGIC, 2018a). In 2014-15, wheat exports contributed \$5.5 billion to the Australia economy – half of the value of total grain exports (ABARES, 2015).

Barley for animal feed and brewing, and oats and triticale, are the other major winter cereal crops in Australia. Barley is the second most important winter cereal in Australia after wheat, with around 9.5 million metric tonnes produced annually. WA is the leading producer of barley in Australia, producing over a third of the nation's production. Table 3.3 lists barley production for each State.

Barley exports were over \$2.1 billion in 2014-15 (ABARES, 2015). Around 40 per cent of Australian barley went to malting for beer and the remainder for animal consumption (PwC, 2011). Although barley is grown in most areas where wheat is grown, it has an average yield of around 2 tonnes per hectare which is slightly higher than wheat.

Table 3.3 Australian barley production by State, average 2014-2016

State	Production ('000 tonnes)
Western Australia	3,290
South Australia	2,069
New South Wales	1,973
Victoria	1,934
Queensland	255
Tasmania	18
Total	9,539

Source: AEGIC (2018b)

In WA 90 per cent of wheat and barley is exported, while in SA 70 per cent of cereal grain produced is exported. Cereals grown in Vic., NSW and Qld are used mainly to meet domestic uses, with around half of production exported in years of good production. In lower production years, nearly all the cereals grain grown in Vic., NSW and Qld are used for domestic human and animal consumption.

3.2.3 Canola

Oilseed crops are used for vegetable oils and livestock feed. Canola makes up around 90 per cent of oilseed production. Around 4 million hectares of canola are grown, producing over 4 million tonnes. Canola is the third largest winter crop behind wheat and barley and it is grown in WA, NSW, Vic. and SA (Table 3.4). Around 20 per cent of the canola grown is genetically modified to be tolerant to non-residual, broad-spectrum herbicides.

Table 3.4 Australian canola production by State, average 2014-2017

State	Production ('000 tonnes)
Western Australia	1,685
New South Wales	1,025
Victoria	693
South Australia	376
Total	3,779

Source: AEGIC (2018c)

3.2.4 Pulses

Pulses are grain legumes used for human consumption and animal feed. The main pulses grown in Australia include lupins, field peas, and chickpeas; plus other pulses such as faba beans, lentils, and vetch. Over 2 million tonnes of these pulses are produced each year, mainly in NSW, WA, and SA (Table 3.5) (AEGIC, 2018d). When grown in rotation with cereals, pulses improve soil fertility by fixing nitrogen in the soil and they provide a supportive disease and pest break.

Lupin varieties grown are the ‘narrow leaf lupin’ (*Lupinus angustifolius*) and the larger seeded and broader leaf *Lupinus albus* or ‘white lupin’. The higher protein narrow leaf lupin is used for stock feed whilst the white lupin is generally used for human consumption. Field peas mostly are grown in SA, Vic. and WA. They are a break crop like lupins but they can be sown later than lupins and on a wider range of soils. Most of the field pea crop is exported for human consumption in Asia and the Middle East, and for stock feed in Europe. Chickpeas are another break crop, produced mainly in NSW with smaller areas grown in Qld and Vic.

Table 3.5 Australian pulse production by State, average 2013-2017

State	Production ('000 tonnes)
New South Wales	580
Western Australia	479
South Australia	459
Queensland	295
Victoria	291
Total	2,104

Source: AEGIC (2018d)

3.2.5 Crop rotations

Crop rotations are an important characteristic of cropping systems. Grains are grown in sequences of various crops and pastures over time to maintain soil nutrients, and to control weed, pest and disease problems. The range and variation of crop rotations greatly complicates the development of an EDM for grains.

Typical sequences of crops grown in the south-eastern grains industry include several cereal crops, a pulse and an oilseed. Pulses and oilseeds in the cereal crop sequence provide benefits in nutrient supply, disease and weed control and soil health. Farmers do not adhere rigidly to a set rotation of

activities but opportunistically adjust the length or nature of each phase of a rotation, depending on seasonal outlook, weed burdens, disease risks and relative commodity prices.

Southern Region

Common crop sequences in the south-eastern grains industry are indicated by the rotations used in the Sustainable Cropping Rotations in a Mediterranean Environment (SCRIME), a research project established in 1998 on the Wimmera on the grey self-mulching clay of the Victorian Wimmera region, conducted by the Victorian Department of Primary Industries since 1990. The crop and pasture activity sequences of the SCRIME experiment, listed below, are 3-part or 6-part rotations, with standard fertilizer and chemical inputs, and with most activities sown using minimum tillage. The rotations analysed were:

- Continuous Wheat across all years
- Pea/Wheat/Barley across all years
- Vetch/Wheat/Barley
- Canola /Wheat/Pea
- Canola/Wheat/Pea Conventional Tillage
- Lucerne/ Lucerne/ Lucerne/Canola/Wheat/Pea
- Vetch GM/Canola/Pea/Medic/ Wheat/Barley
- Canola /Wheat/Pea with No Tillage
- Fallow/Wheat/Chickpea until 2011, then changed to Fallow/Wheat/Lentil.

Northern Region

Producers in the northern region operate in a challenging cropping environment where declining soil fertility is prevalent (GRDC, 2019a). For this reason, chickpeas have been a popular crop used to boost soil nitrogen and improve soil quality.

Popular crops in northern region crop rotations are as follows:

- Chickpeas
- Faba beans
- Field Peas

- Soybeans and Mungbeans
- Canola
- Sorghum.

Western Region

Tables 3.6 and 3.7 below provide examples of farm cropping systems in the western region. Farms have varying soil types across paddocks with considerable variation in fertility, soil moisture holding capacity and cropping history. Different crop sequences are adopted depending on the soil type.

Table 3.6 Example of a farm cropping system in the Kwinana East Port Zone, WA

Soil Type		Year 1	Year 2	Year 3	Year 4	Year 5
Heavy	Crop	Wheat	Barley	Wheat	Barley	Fallow
	Yield (t/ha)	3	2.8	2.3	2.8	-
Medium	Crop	Wheat	Wheat	Barley	Fallow	Canola
	Yield (t/ha)	2.6	2.0	2.8	-	1.4
Light	Crop	Wheat	Oats	Pasture		
	Yield (t/ha)	2.6	1.89	-		

Source: GRDC (2017)

Table 3.7 Example of a farm cropping system in the Geraldton Port Zone, WA

Soil Type		Year 1	Year 2	Year 3	Year 4	Year 5
Heavy	Crop	Canola	Wheat	Wheat	Barley	
	Yield (t/ha)	0.82	1.73	1.73	2.24	-
Light	Crop	Canola	Wheat	Lupin	Wheat	Wheat
	Yield (t/ha)	0.82	1.73	1.48	1.73	1.73

Source: GRDC (2017)

3.3 Major Markets for Australian Grains

Wheat

Different classes of wheat are produced in Australia for a multiple number of end-uses for different markets. There are three categories of wheat: Premium Hard Wheats, Multi-Purpose Wheats and Speciality Wheats (Wheat Quality Australia, 2018). Premium Hard Wheats are the Australian Prime Hard and Australian Hard wheats. These have high protein with high milling qualities. Flour from Australian Prime Hard wheat suits high volume breads, artisan bread, yellow alkaline noodles, fresh ramen and dry white salted noodles. Flour from Australian Hard wheat suits baked products, including pan and hearth breads, Middle Eastern-style flat breads, yellow alkaline noodles, white noodles and steamed breads.

The Australian Standard White and Australian Premium White wheats have multiple uses. These wheats make up the largest proportion of Australia's wheat crop. Flour milled from Australian Standard White and Australian Premium White wheats are used to make a variety of breads and noodles (AEGIC, 2018a). Speciality Wheats are the Australian Noodle Wheat, Australian Premium White Noodle, Australian Soft, and Australian Premium Durum classes. These varieties make up a low proportion of the total Australian wheat crop, with unique characteristics that suit specific end uses.

Around 65 to 75 per cent of Australia's total wheat production is exported each year (AEGIC, 2017). In Table 3.8 is a breakdown of Australia's top 10 wheat export markets. Indonesia is Australia's largest wheat export market, up until 2017 importing over 4 million tonnes annually, valued at \$1.2 billion. Since 2017 pervasive drought in Qld and much of northern and western NSW have curtailed Australia's grain production leading to increased domestic demand, especially for feed grains, and so exports to countries like Indonesia have greatly diminished.

Barley

Over 50 per cent of Australia's annual barley production is exported. In Table 3.9 is the top 10 export markets for barley. China is Australia's largest barley export market, accounting for over 3 million tonnes with an export value of close to \$1 billion annually. Australia is also the leading supplier of malting barley to China, supplying 60 per cent of China's annual demand (Department of Primary Industries and Regional Development, 2018).

Table 3.8 Major export markets for Australian wheat, average 2014-2017

Destination	Quantity (‘000 tonnes)	Value (A\$m)	Per cent of Total Value (%)
Indonesia	4,140	1,200	22
Vietnam	1,497	460	8
China	1,426	428	8
South Korea	1,034	328	6
Japan	898	301	5
Philippines	1,024	287	5
Malaysia	928	281	5
Yemen	901	272	5
India	786	224	4
New Zealand	489	155	3
Other Export Markets	4,873	1,600	29
Total	17,996	5,550	100

Source: AEGIC (2018a)

Table 3.9 Major export markets for Australian barley, average 2013-2016

Destination	Quantity (‘000 tonnes)	Value (A\$m)	Per cent of Total Value (%)
China	3,148	968	59
Saudi Arabia	1,064	290	18
Japan	638	187	11
U.A.E	201	56	3
Kuwait	156	41	2
South Africa	58	21	1
Korea	55	19	1
Taiwan	40	12	1
Oman	39	11	1
Vietnam	33	10	1
Other Markets	120	37	2
Total	5,552	1,652	100

Source: AEGIC (2018b)

Canola

Australia supplies annually 2.5 million metric tonnes of canola to international markets. In Table 3.10 is Australia's top 10 export markets for canola, which account for 99 per cent of the total value of canola exports. The European Union is the leading destination for Australian canola exports, taking over 70 per cent of the total, with these exports used mainly for biodiesel production (AEGIC, 2018c).

Pulses

Australia exports most of its pulse production to international markets. The Indian sub-continent is the leading destination for pulses with around two-thirds of exports shipped to India, Bangladesh, Pakistan, and Sri Lanka annually (Table 3.11).

Table 3.10 Major export markets for Australian canola, average 2014-2017

Destination	Quantity (‘000 tonnes)	Value (A\$m)	Per cent of Total Value (%)
Germany	635	366	25
Belgium	634	359	25
France	288	163	11
China	253	147	10
Japan	174	103	7
Netherlands	180	99	7
Pakistan	102	63	4
U.A.E	110	61	4
Denmark	95	59	4
Vietnam	36	22	2
Other Markets	21	13	1
Total	2,528	1,455	100

Source: AEGIC (2018c)

Table 3.11 Major export markets for Australian pulses, average 2013-2016

Destination	Quantity (‘000 tonnes)	Value (A\$m)	Per cent of Total Value (%)
India	723	619	38
Bangladesh	307	239	15
Pakistan	170	145	9
Egypt	242	135	8
Sri Lanka	94	81	5
U.A.E	88	68	4
South Korea	126	49	3
Netherlands	92	37	2
Saudi Arabia	44	29	2
Malaysia	26	17	1
Other Markets	212	225	14
Total	2,124	1,644	100

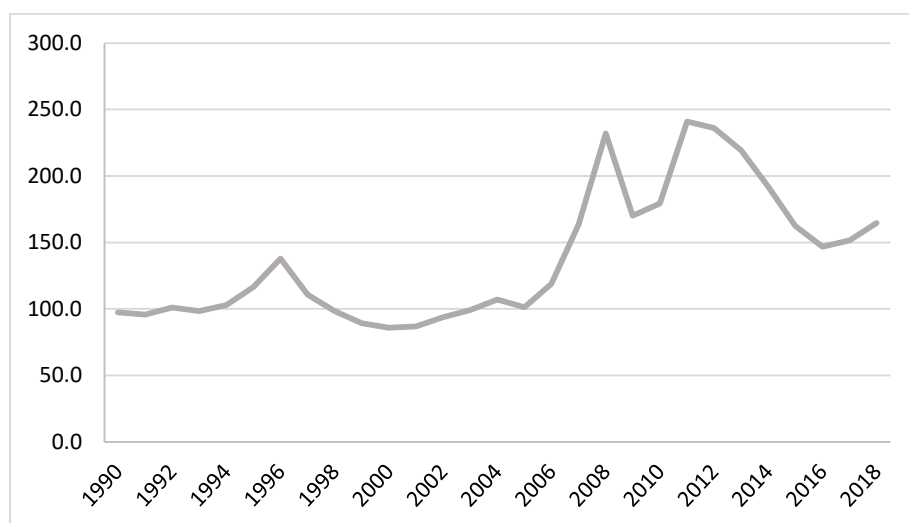
Source: AEGIC (2018d)

Prices for Australian Grains

The price of grain is determined mainly on international markets. Fluctuations in global grain prices and supplies cause volatile incomes for producers. Grain prices are volatile for grain exporting countries like Australia because only a small share of total production enters world trade, and increases and decreases in national production of countries can significantly add to or subtract from grain available for trade, causing significant swings in aggregate trade volumes and associated swings in prices. World market conditions have varied dramatically over the past 10 years. During the 2007-08 global food crisis, world food prices rose to very high levels. Between 2006 to 2008, average world prices for grains increased sharply – rice rose by 217 per cent, wheat by 136 per cent, maize by 125 per cent, and soybeans by 107 per cent (FAO International Commodity Price Database, as cited by Haugh *et. al.* (n.d)). Low world grain stocks were a main cause, with stock levels in 2006-07 falling to their lowest levels in almost 20 years (FAO, 2009). A combination of other interrelated factors included production shortfalls, increasing oil prices, collapse of share markets, greater demand for biofuels, a depreciating US dollar and growing incomes in emerging economies (FAO, 2009). The successive droughts in Australia prior to 2005-06 contributed to the upwards pressure on prices of various grains, in particular, wheat prices. Domestic wheat prices in Australia rose by 38 per cent in 2012-13 when low annual rainfall reduced national wheat production (IBISWorld, 2017). Food prices have been very volatile since the global food crisis, with food prices falling after 2007-08 only to then rise again during 2011-12. Cereal grain prices subsequently dropped again below 2009-10 levels as shown in Figure 3.2.

This was caused by a global grains glut with grain stocks reaching their highest levels in 30 years (Ruitenberg, 2015). Drought in south-eastern Australia in 2018 saw little grain going to export markets. Domestic wheat prices rose sharply from the medium-term average of \$280/t to over \$400/tonne. Grain price instability will continue to be influenced by (i) increasingly volatile weather and severe weather events; (ii) a growing world population; (iii) barriers to trade; (v) oil price fluctuations; and (v) changes in the use of biofuels, and (vi) changes in consumer preferences (e.g. increased vegetarianism in Australia).

Figure 3.2. Cereal grains price index, 1990-2018



Source: FAO Food Price Index

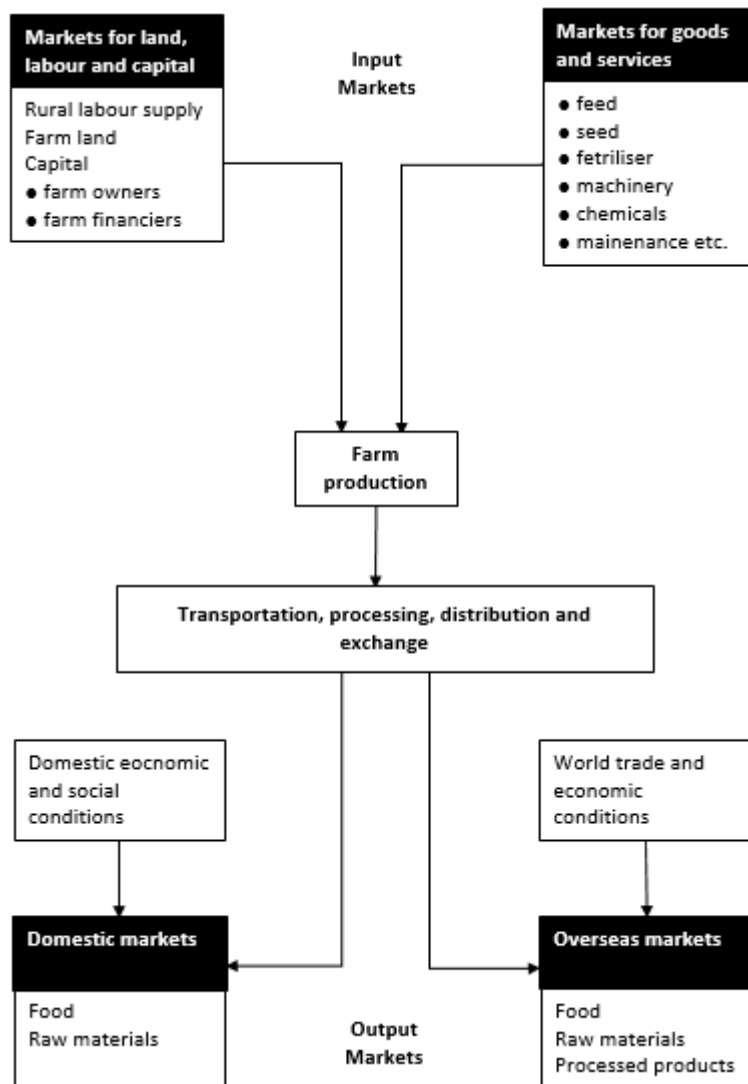
Supply and Value Chains

Producing grain on the farm and the marketing of grains to users involves many stages. A supply chain describes the network of processes and activities necessary to bring a farm product through different stages of production and marketing to delivery to the final consumer.

The various input and output stages in the production and marketing (processing, distribution and exchange) of agricultural commodities are illustrated in Figure 3.3. Here, farm production of grains requires the use of various farm inputs including factors of production (land, labour and capital) and other intermediate inputs (e.g. seed, fertiliser, machinery, chemicals, transport, fuel and equipment etc.). Farm products are then transported, processed, distributed and sold to either the domestic or export markets for use in food, raw materials and other processed products. Marketers play an

important role in the supply chain through linking growers with other market participants. They typically purchase grain from growers, identify buyers, and coordinate the logistics and delivery of grain to such customers from both the domestic and international markets.

Figure 3.3 Marketing channels for agricultural commodities



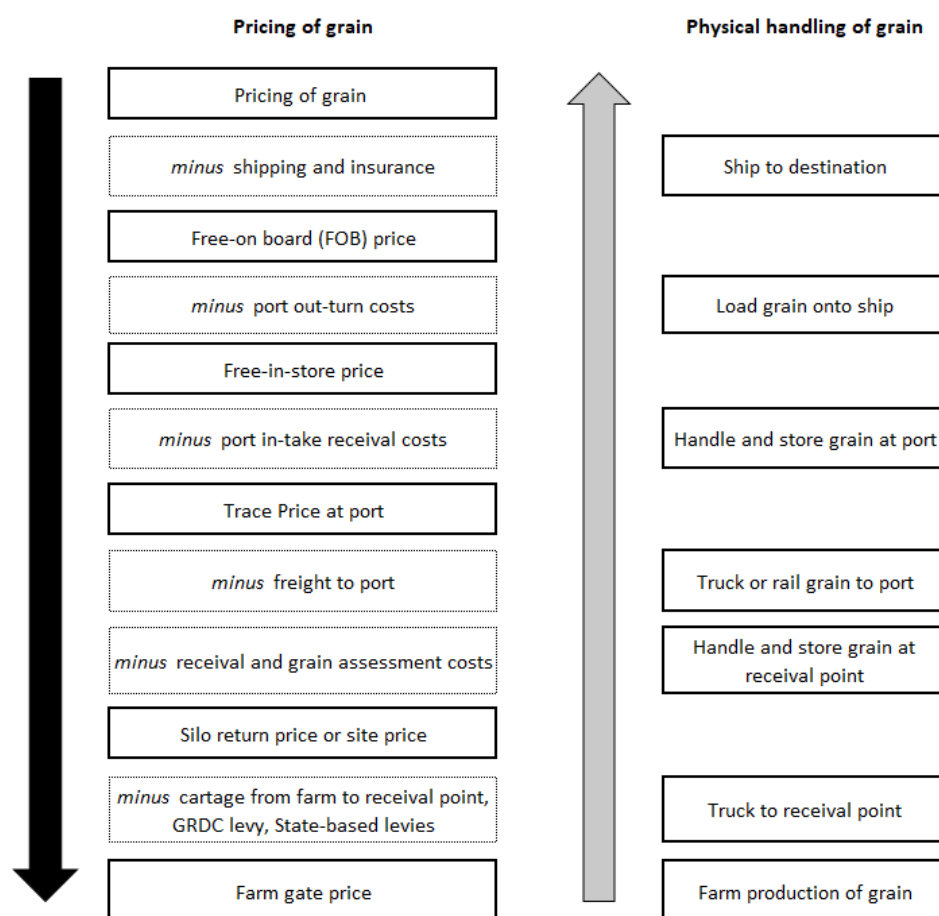
Source: Malcolm *et al.* (2009)

Related to supply chains are value chains. Value chains comprise the same network of supply chain entities involved in the production and distribution of goods to end users. A value chain, however, places particular emphasis on the distribution of the final sales value of a commodity along the supply chain network. The focus lies on how value is sequentially added to a product as it is carried along the different stages of its supply chain. Both concepts are frequently used interchangeably as value chains maps will often encompass identical elements to supply chain maps.

An industry value chain map for an exported grain is shown in Figure 3.4 below. As depicted on the right hand side, the physical flow of grain moves from farm to its export destination. However, the pricing of grain (left hand side) is principally determined on international markets with supply chain costs being sequentially deducted to generate a farm gate price (Stretch *et al.*, 2014). Value is added along each stage of the supply chain.

The performance of an agricultural value chain is measured by the chain's economic surplus (total chain profitability) that it creates, captures and distributes among chain members. Chain surplus is the difference between aggregate willingness to pay by customers and the cost to the value chain of meeting their customers' requirements. All participants along value chains create value for consumers. Most do this by operating individually and collectively, in markets, in domestic and international economies.

Various determinants can affect the prices and costs of grains and grain products in domestic and overseas markets. As pointed out by Stretch *et al.* (2014), the pricing of grain at the farm-gate level is mainly determined by the prevailing world commodity prices, with supply chain costs being sequentially deducted to generate a farm gate price.

Figure 3.4 Value chain for export grains

Source: Stretch *et al.* (2014)

In Table 3.12 below, a breakdown is provided for export grain supply chain costs by the main bulk handlers in each State for 2013-14 (Stretch *et al.*, 2014). Wheat was the commodity used to illustrate the value chain costs, as it is the main grain grown and exported by Australian grain producers. It was assumed that wheat was delivered to a site 200 km from port, and that the FOB price of \$320/t was used across all terminals in all States. Although the physical handling of grain starts at the farm level and moves to its export destination, the pricing of grain is primarily determined on international markets with the FOB price, with costs along the supply chain deducted to arrive at the farm gate price. Presuming the activities are profitable, the estimated export value chain costs in Table 3.12 indicate the 'net value add' process to grain commodities going from farm gate to the export markets. As shown, in 2013-14, export value chain costs for producers was least for WA at \$58.93/t, whereas Qld had the highest export supply chain costs of \$72.64/t.

Table 3.12 Australian grain export supply chain costs (2013-14)

2013/14	WA (CBH)	NSW (GrainCorp)	SA (Viterrra)	QLD (GrainCorp)	Vic (Emerald)
	(\$/t)				
FOB price (assume same at all ports)	320	320	320	320	320
Port charges	21.90	20.99	21.78	24.11	21.11
FIS price	298.10	299.01	298.23	295.89	298.89
Up country receival and shrinkage	11.49	15.18	13.64	15.39	15.85
Storage for three months	-	4.50	3.30	4.50	4.80
Rail frieght - 200 km	19.00	23.00	27.20	23.00	23.40
GRDC levy	2.73	2.71	2.59	2.64	2.64
State researchand biosecurity levies	0.30	-	0.50	-	-
End point royalties	3.00	3.00	3.00	3.00	3.00
Other					
Total supply chain cost before rebates	58.42	69.38	72.01	72.64	70.80
Potential rebates from bulk handler	-1.75	-	-1.10	-	-
Supply chain cost after rebates	56.67	69.38	70.91	72.64	70.80
Farm gate price	263.33	250.62	249.09	247.36	249.20

Source: Stretch *et al.* (2014)

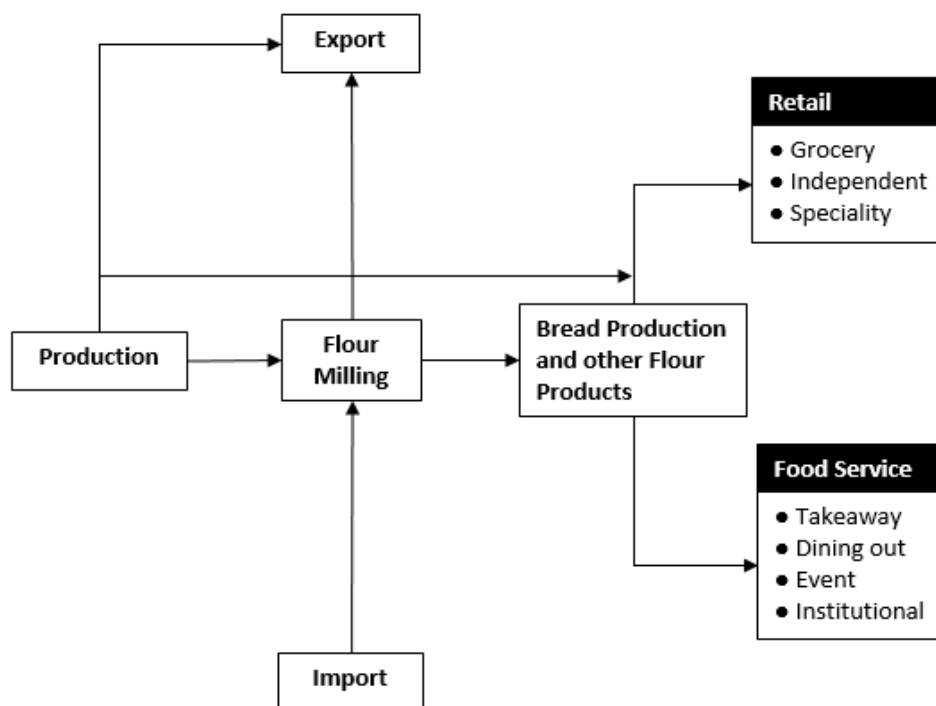
Stretch *et al.* (2014) highlighted that in Australia, supply chains in WA and SA are structured to deliver grain one way to port, with around 85-95 per cent of the grain produced in these two states being exported. On the other hand, around 50 per cent of grain grown in eastern Australia is consumed locally, which results in grain going through a different supply chain and value-adding process. In terms of wheat, the grains industry can process and market around 10-15 per cent of wheat production into domestic consumer markets in a variety of products (Spencer and Kneebone, 2012). Most food uses for wheat include wheat flour products such as bread and pastry products, and consumer and foodservice flour products. While it has been mentioned that the wheat industry is primarily export driven, with 85 per cent of raw wheat being exported, the flour industry on the other hand, is the opposite, with only around 10 per cent of flour production being exported overseas (Spencer, 2004). The supply and value chain for flour and other wheat products is more complex than for exported wheat. A simple value chain map for grain and flour products is shown in Figure 3.5.

The prices of wheat and other grains is a major cost in the production of flour. Spencer (2016) noted that the farm gate prices represented 34 per cent of the retail value of flour. As wheat and grains move along to be processed as flour at the wholesale level, a suitable margin over processing costs is applied. Finally, as flour is turned into bread and other flour products, a further target margin over cost is applied, with retail prices being constrained by competition between major grocery chains and discounters.

Major Competitors

Globally, Australia is a relatively small grain producer. An average of 25 million tonnes of wheat is produced per annum in Australia which accounts for only 3.6 per cent of world wheat production (see Table 3.13). An average of 18.5 million tonnes per annum is exported, accounting for over 70 per cent of the average annual production (Table 3.14). Annual global exports of wheat are around 200 million tonnes.

Figure 3.5 Grain and flour product supply chain map



Source: Spencer and Kneebone (2012)

South East Asia (SEA) is the largest market for Australian wheat, importing an annual average of 42.9 million tonnes over the five years up to 2017, valued at A\$2.6 billion per annum (GRDC, 2018b). The competitive advantage of Australian wheat producers and sellers in the SEA market has been supported by the close proximity of these markets to Australian grain ports, as well as some grain quality attributes of particular Australian wheat grades such as Australian Noodle Wheat.. In recent years, however, there has been a strong surge of competition from Russia and Ukraine in SEA markets, because of their lower production costs and greater availability of their grain.

Between 2012-13 and 2016-17, Russia's wheat exports averaged 21 million tonnes per annum, a world share of over 13 per cent. The average growth in Russia's wheat exports was 27 per cent during this period (ABARES, 2017). This rise in exports for Russia stems from several factors, including favourable exchange rate movements, their modernisation of agronomic practices, increased investment in farm machinery and logistics infrastructure, and a downturn in international shipping freight rates over this period. It is projected that Russia's wheat exports will increase by 60 per cent between 2015 and 2030 (Kingwell *et al.*, 2016a).

Ukraine on the other hand averaged over 12 million tonnes of wheat exports per annum over 2013-2017.. Their average annual growth rate in wheat exports was 28 per cent (ABARES, 2017). Like Russia, the rise in Ukraine's exports have been the result of several factors similar to those previously listed for Russia. As noted by Kingwell *et al.* (2016b), there is significant scope for Ukraine to increase its international competitiveness by increasing its area sown to wheat, further increasing investments in agricultural infrastructure, and more widely adopting modern farming methods.

Table 3.13 Top 10 wheat producing countries, average 2013-2017

Country	Production (Million Tonnes)	Per cent of World Share
China	125.6	17.5
India	91.4	12.7
United States	58.7	8.2
Russian Federation	56.5	7.9
France	37.4	5.2
Canada	30.7	4.3
Australia	25.8	3.6
Germany	25.2	3.5
Pakistan	24.9	3.5
Ukraine	23.4	3.3

Source: ABARES Agricultural Commodity Statistics

Table 3.14 Top 10 wheat exporting countries, average 2013-2017

Country	Exports (Million Tonnes)	Per cent of World Share (%)
European Union	30.9	19.6
United States	26.6	16.8
Canada	21.8	13.7
Russian Federation	21.1	13.3
Australia	18.5	11.7
Ukraine	12.7	8.0
Kazakhstan	7.2	4.4
Argentina	6.6	4.2
Turkey	5.2	3.3
India	3.5	2.2

Source: ABARES Agricultural Commodity Statistics

3.4 Policy Environment

Australia

The Australian grains industry has a long history of government regulation. Historically, the domestic and export sales for wheat were regulated under single desk marketing arrangements; returns to growers were pooled nationally and the prices received by growers averaged. These marketing arrangements were carried out by the Australian Wheat Board (AWB) from 1939 to 1999, and later by its successor, AWB International from 1999 to 2008 (Productivity Commission, 2010). The scope of single desk marketing arrangements was reduced in 1989 when the Commonwealth Government deregulated the domestic market for wheat sales. The export sales for wheat continued to operate under the single desk monopoly until August 2007 when non-bulk exports were deregulated. In June 2008, the single desk marketing arrangements were abolished when bulk wheat exports were deregulated. Subsequently a significant number of new participants entered the bulk wheat exporting market, bringing greater competition and more marketing options for growers.

The momentum for change to the export marketing arrangements for wheat was partly the result of successful deregulation of the export of other grains (Productivity Commission, 2010). Prior to the 1990s, single desk marketing arrangements also prevailed in the domestic and export markets for barley, sorghum, maize, oats, oilseeds, lupins and rice. The marketing arrangements were maintained by both (i) the various statutory marketing boards for each grain type and (ii) a single bulk handling authority in each State. Statutory marketing boards were provided with exclusive rights to acquire grain, whereas bulk handling authorities were given exclusive rights to receive grain. The 1990s and early 2000s saw consolidation in which a number of bulk handling companies and statutory marketing boards were privatised and merged, creating entities that performed dual functions. It was during this time that deregulation of the marketing arrangements for these grains also occurred.

Overseas

The wheat industry of other exporting countries share similarities and differences in terms of their marketing and institutional arrangements.

By contrast to the Australian wheat industry, the US wheat industry has historically embraced a free enterprise approach in terms of agricultural marketing, arguing against AWB's single desk marketing arrangements during its existence (Watson *et al.*, 2017). Another distinguishing feature of the US wheat industry is the utilisation of market intervention programs to counter adverse fluctuations in prices, revenues and production. These intervention programs comprise various federal subsidies for farm businesses and support mechanisms that are substantial in magnitude—around \$25 billion a year (Edwards, 2016).

The Canadian wheat industry on the other hand, bears a lot in common with the Australian wheat industry. Previously, the Canadian Wheat Board (CWB) operated as the sole marketing agency for western Canadian wheat and barley. Deregulation of wheat export occurred in 2012 as the CWB's single-desk monopoly position was removed. Since deregulation, two new agencies play a more prominent role in the market development and quality management functions: the Canadian Grains Commission (CGC) and the Canadian International Grains Institute (CIGI). The CGC is a federal government agency that regulates the grain handling industry, conducts scientific research into grain quality and safety, and provides technical advice and expertise to overseas customers (Watson *et al.*, 2017). The CIGI, on the other hand, is a not-for-profit education and market-support organisation that serves to drive the market development of agricultural products. Unlike Australia, where the market

development function was lost or transferred to the private interests of individual traders following export wheat deregulation, the market development function remained as a public function in the Canadian wheat industry (White *et al.*, 2015).

3.5 Summary

This chapter provided an overview of the vastness and complexities of the Australian grains industry. The industry produces a multitude of grain commodities consisting of cereals grains, oilseeds and pulses across three cropping regions– northern, southern, and western. The major winter cereals consist of wheat and barley. Canola is the third largest winter crop behind wheat and barley and along with pulses, can be used as break crops in crop rotations. Each crop has a multiple number of end uses across different markets.

Chapter 4 Conceptual Specifications and Review of Industry Data

4.1 Introduction

In this chapter, conceptual issues along with data and information used to disaggregate the Australian grains industry for EDM purposes is reviewed and discussed. Section 4.2 conceptualises the Australian grains industry in a manner that can be represented using an EDM. Section 4.3 specifies the approach in regionally disaggregating the model into the three agroecological regions. Section 4.4 reviews data on the production, distribution and use of Australian grains and grain products to be used in calibrating the EDM.

4.2 Conceptualisation of the Industry

As highlighted in the previous chapter, the Australian grains industry is vast in scope. The industry produces a multitude of grain commodities consisting of cereals grains, oilseeds and pulses across three cropping regions. The range of grains and cropping rotations, competing end uses of these grains, as well as the different and numerous supply chains in the three regions make the task of constructing a grains industry EDM very complex. Accurately capturing every detailed aspect of the industry in an EDM is conceptually difficult and impractical. Instead, the purpose here is to provide a stylised, yet useful, representation of the entire grains industry using an EDM.

Also as highlighted in the previous chapter, crop rotations are a common feature of the grains industry. Under such a system of rotations, crops are grown in particular sequences on the same area of land over several years. This allows crops within a rotation to have complementary effects on subsequent crop yields through disease and pest management, soil fertility, and weed control. As such, the decision to grow a crop is rarely made in isolation, as grain cropping is typically a sequential system of activities (Malcolm *et al.*, 2005; Malcolm & Armstrong, 2016). This adds an extra layer of complexity in the modelling process due to the added time dimension.

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. This means that the sequential rotation of crops in a field over several years cannot be simply captured using such a framework. However, a steady-state synopsis can be generated by assuming that each phase of a rotation sequence is present during each year (see Malcolm &

Armstrong, 2016, pp. 1-2). This means that instead of examining the problem across time, we can instead examine the problem at a particular point in time. Figure 4.1 provides a diagrammatic of this concept.

Figure 4.1 Diagrammatic representation of addressing crop rotations in a comparative static framework

	Year 1	Year 2	Year 3	Year 4
Area 1	Wheat	Barley	Canola	Break crop
Area 2	Barley	Canola	Break crop	Wheat
Area 3	Canola	Break crop	Wheat	Barley
Area 4	Break crop	Wheat	Barley	Canola

In this example, the crop rotation consists of four grain types: wheat, barley, canola and a break crop. The entire cropping paddock 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 is sequentially rotated along each cropping area. This same conceptualisation of the treatment of rotations to form a steady state appraisal is used also in mathematical programming models of farming systems. A well known Australian example is the MIDAS (Model of and Integrated Dryland agricultural System) model of typical broadacre Australian farming (Kingwell & Pannell, 1987; Kingwell, 1996; O’Connell *et al.*, 2006; Thamo *et al.*, 2013).

A comparative static framework such as an EDM cannot readily capture and model the dynamic nature of sequential rotations across time (horizontally). Instead, the problem must be examined from the perspective of a point in time (vertically).

4.3 Regional Disaggregation

The model system disaggregates the Australian industry according to the three agroecological regions defined by the GRDC—western, southern and northern. Each region is differentiated by factors such as climate and weather patterns as well as soil conditions that determine the types of grains suitable for growing as well as their yields. For the purposes of this study, each region is represented by separate EDMs.

Modelling the grains industry requires deciding on the types of grains to include in the EDM system. Due to the wide-ranging variety of crops produced by the industry, it is impractical to incorporate the entire set of crops in the model due to data and conceptual limitations. Instead, only the major crops are modelled. When combined, these selected crops represent a standard cropping sequence.

A common and profitable choice for growers is to rotate wheat, barley and canola with pulses such as field peas, lupins or chick peas also being considerations (Malcolm *et al.*, 2009). Taking this into account, a practical choice is for wheat, barley and canola to be included as common crops in each regional EDM, along with a regional specific break crop.

A four crop rotation system is applied to each regional EDM as follows:

- Western Region: Wheat/Barley/Canola/Lupins
- Southern Region: Wheat/Barley/Canola/Peas
- Northern Region: Wheat/Barley/Canola/Chickpeas.

These cropping sequences represent the cropping sequences across each region's entire cropping industry.

4.4 Production, Distribution and Use of Australian Grains and Grain Products

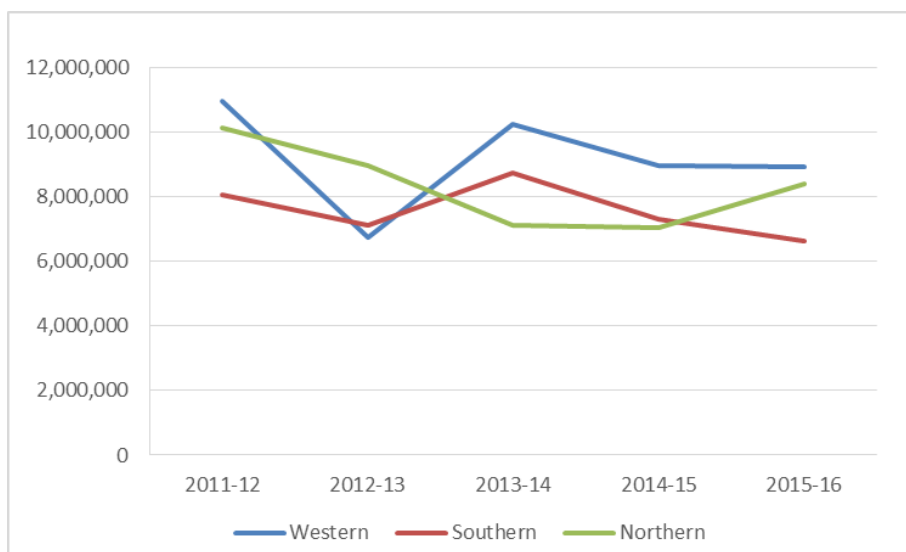
Information and data on the production, distribution and use of Australian grains and grain products for this study is obtained from various sources such as the Australian Crop Forecasters (ACF), ABARES, the GRDC, AEGIC, IBISWorld and Feed Grain Partnership. In most cases, the time period used to 2011-12 to 2015-16. It is assumed that this five year period accounts for a medium run length of industry activity.

4.4.1 Farm Production

Production during this period has fluctuated. For instance, favourable winter and spring rainfall conditions enabled record levels of winter crop production in 2011-12. Wheat production reached a record level of over 29 MMT. This was offset the following year in 2012-13 by dry seasonal conditions. Yield levels of wheat fell by 24% from the previous season to 22.8 MMT during this season.

Tables 4.1 to 4.4 provide summaries of the average production of wheat, barley and canola for the years 2011-12 to 2015-16. Over this period, an average of 25 MMT of wheat was produced, the majority of this coming from the western region (9.2 MMT), followed by the northern region (8.3 MMT) and the southern region (7.6 MMT). The figures below depicts the fluctuation in production across all three cropping regions over this period.

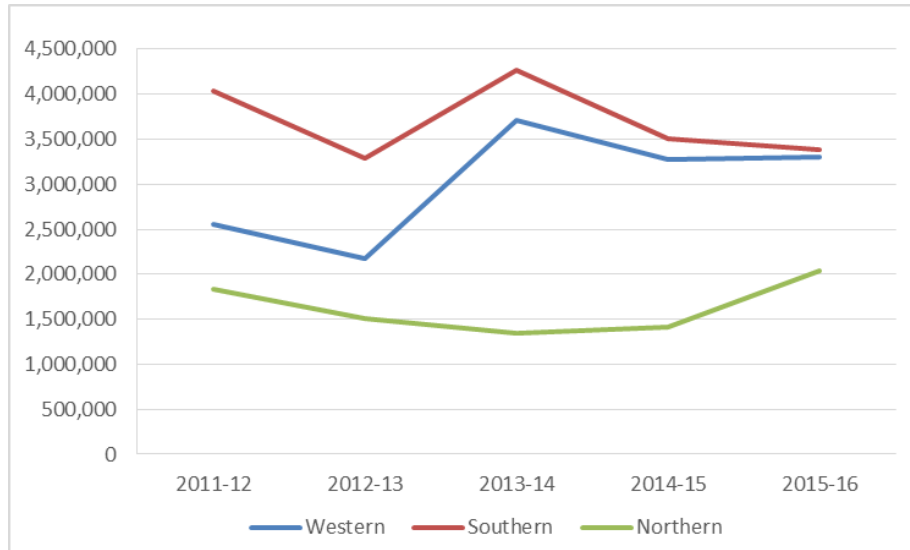
Figure 4.2 Wheat production across all cropping regions 2011-12 to 2015-16 (metric tonnes)



Source: Australian Crop Forecasters (ACF), Supply and Demand Report

Barley production averaged 8.3 MMT over this period, largely lead by dominant production levels in WA (3 MMT) and SA (2 MMT).

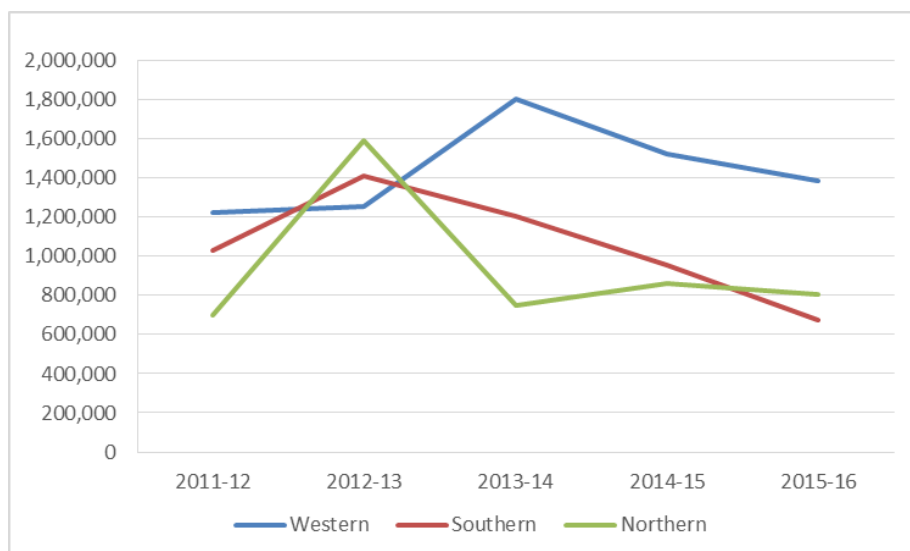
Figure 4.3 Canola Barley production across all cropping regions 2011-12 to 2015-16 (metric tonnes)



Source: Australian Crop Forecasters (ACF), Supply and Demand Report

Canola is the third largest broad acre crop after wheat and barley with production averaging 3.4 MMT from 2011-12 to 2015-16.

Figure 4.4 Canola production across all cropping regions 2011-12 to 2015-16 (metric tonnes)



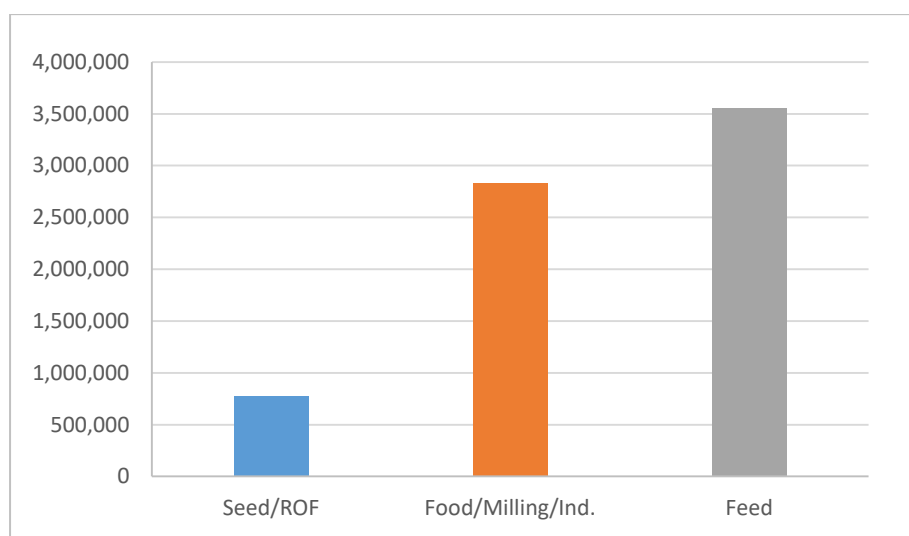
Source: Australian Crop Forecasters (ACF), Supply and Demand Report

4.4.2 Secondary Processing and Products

Flour Milling

As shown in Figure 4.5, an average of 2.8 MMT per annum of wheat was used for Flour Milling for food and industrial purposes during the 2011-12 to 2015-16 period. This represents around 13% of average grain production (ignoring carry in supply).

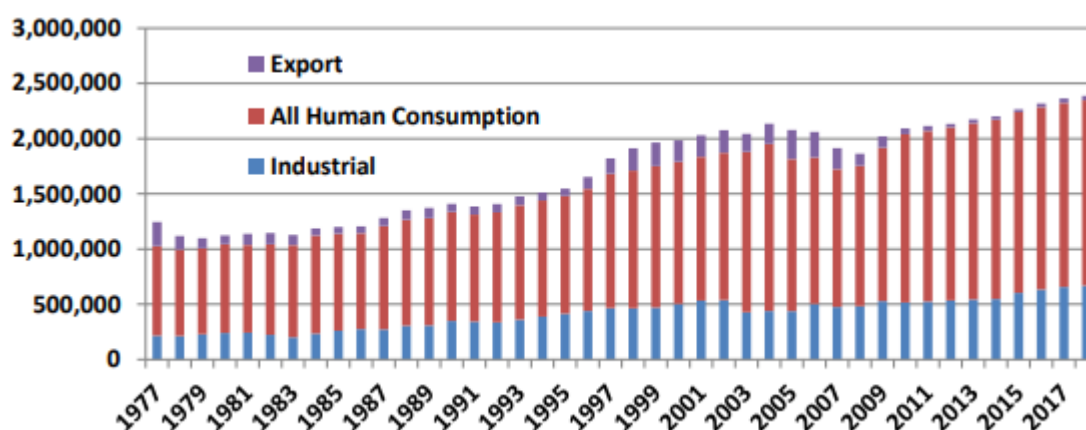
Figure 4.5 Domestic uses of wheat in Australia, annual average (metric tonnes) between 2011-12 to 2015-16



Source: Australian Crop Forecasters (ACF), Supply and Demand Report

Based on information from JCS Solutions, an estimated 3.0 MMT of wheat was required to produce 2.3MMT of flour in 2016, equating to a wheat to flour conversion rate of around 77%. Figure 4.6 provides a historical breakdown of flour usage between the years 1977 to 2018. Flour for human consumption through baking is the largest demand, followed by industrial use for starch and ethanol production. The export of flour has declined and is estimated to represent a minor portion of flour milling production.

In addition to flour, flour millers also produce a by-product called millmix. This by-product is a combination of bran and pollard and is used as a feed ingredient for livestock. The volume of millmix produced is related to the volume of wheat milled and the efficiency of the extraction rate. This volume is approximately that of the residual volume between the input wheat and extracted flour. Based on 2016 extraction rates, millmix production was at 650,000 tonnes per annum.

Figure 4.6 Australian flour production 1977-2018 (tonnes)

Source: 1977 – 2009 Flour Millers' Council (ABS), 2010-2014 export flour ABARES, human consumption JCS Solutions estimate based on domestic population growth, industrial JCS Solutions estimate.

Stockfeed Manufacturing

The stockfeed manufacturing sector is the largest domestic market for Australian grain. In 2016, it was estimated that around 9.5 MMT of grains was used to produce 13 MMT of animal feed (JCS Solutions, 2016). Based on ACF data, it is estimated that between the years 2011-12 to 2015-16, an average of 3.2 MMT (15% of total average annual production) of wheat and 0.9 MMT of barley (55% of total average annual production) was used for stockfeed production.

Table 4.1 provides the breakdown of feed use by State and industry. Vic, Qld and NSW have the largest feed demands driven largely by the dairy, beef and poultry meat sectors.

Inputs in the production of stockfeed, include:

- 72% of raw inputs are grains, including various cereal grains such as wheat and barley, whole oilseeds such as canola seed, and various pulses;
- 10% of inputs are vegetable protein meals, including canola meal;
- 4% of inputs are millmix; and
- The remaining 14% of inputs consist of animal protein meals, fats and oils, roughage, molasses, macro minerals, other co-products and premix.

Table 4.1 Feed use by industry sector and State (tonnes/annum) 2015-16

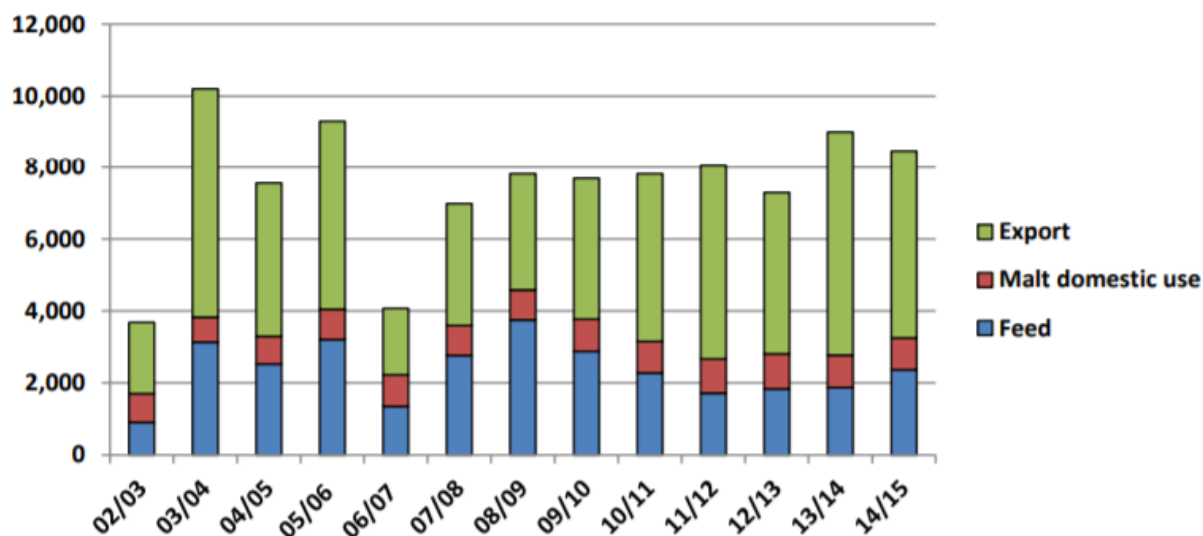
	NSW	Vic	Qld	SA	WA	Tas	Total
Poultry Meat	1,007,832	714,102	651,817	583,091	191,231	28,160	3,176,233
Layer	282,134	218,426	263,931	59,157	72,809	13,652	910,109
Pig	253,389	328,207	361,421	308,488	195,864	8,206	1,455,576
Dairy	447,884	1,876,997	191,864	153,361	145,990	242,637	3,058,734
Beef	1,112,106	259,431	1,907,478	99,995	122,994	41,325	3,543,329
Sheep	28,905	48,441	3,938	33,833	128,364	2,839	246,320
Horse	138,127	92,804	93,164	22,542	18,105	6,235	370,977
Aquaculture	6,000	2,200	22,000	6,000	6,000	98,000	140,200
Other	36,722	56,306	21,797	9,787	14,472	4,649	143,733
TOTAL	3,313,099	3,596,915	3,517,409	1,276,254	895,829	445,703	13,045,210

Source: JCS Solutions estimates

Malt Manufacturing

Besides being an input in feed production, malt grade barley also plays a prominent role in malt production. From 2011-12 to 2015-16, an average of 223,531 tonnes per annum of barley produced was used for malting, representing around 14% of total average annual barley production during the period. Figure 4.7 provides a historical breakdown of barley use in domestic feed, malting, and exports from 2002-03 to 2014-15.

When barley is malted, there is a loss in volume in caused by steeping, respiration and rootlet loss. It is estimated that this loss in volume is less than 10% (Barley Australia, 2017).

Figure 4.7 Barley use in domestic feed, malt and exports 2002-03 to 2014-15 ('000 tonnes)

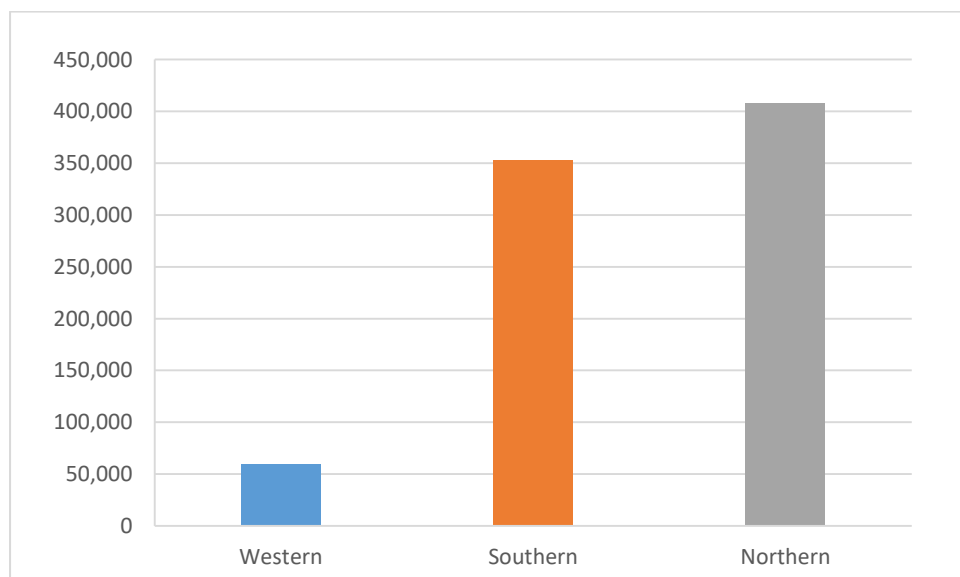
Source: JCS Solutions estimates

Oilseed Crushing

Canola is the largest oilseed crop grown in Australia. As shown in the previous chapter in Table 3.4, the Australian grains industry averaged 3.8 MMT of production annually over the 2014-2017 period, with production being the highest in the western region, averaging nearly 1.7 MMT annually. This was followed by the southern region (1.1 MMT annually) and the northern region (1.0 MMT annually).

Canola seed is crushed and the resulting oil is used for human consumption and the meal used for animal feed. The Australian Crop Forecasters estimate that an average of 0.8 MMT of canola was crushed annually from 2011-12 to 2015-16. Figure 4.8 below provides a regional breakdown of the quantity of canola seed used in crushing. As can be seen, the northern region crushes the greatest amount of canola seed with over 40% of annual production used for this purpose. This is followed by the southern region where over 30% of annual canola production is domestically crushed. Being heavily export oriented, the western region only processes around 4% of its annual production. Based on data from the United States Department of Agriculture (USDA), the extraction rate for canola meal is around 57%, and the extraction rate for canola oil is around 41% (USDA, 2017).

Figure 4.8 Domestic canola processed by crushers across regions, annual average (tonnes) between 2011-12 to 2015-16



Source: Australian Crop Forecasters (ACF), Supply and Demand Report

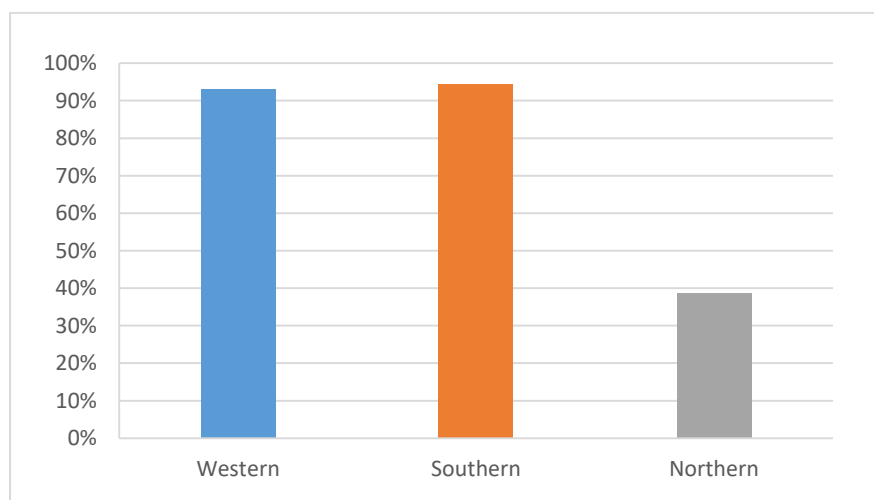
4.4.3 Domestic and Export Use

Grain Exports

Australia is a significant grain export nation. The volume of exported grain reflects surplus stocks where productions exceeds domestic demand. The export profile of the Australian grains industry varies greatly across each grain commodity.

The industry's most important export grain is wheat. Around 75% of production from 2011-12 to 2015-16 was exported. As shown in Figure 4.9, almost the entire annual wheat production from the western and southern Regions is exported (over 90% of total production). The northern region on the other hand exported less than half its average annual production of wheat during this period (39%).

Figure 4.9 Annual average exported wheat as a proportion of total production (%), by cropping region 2011-12 to 2015-16



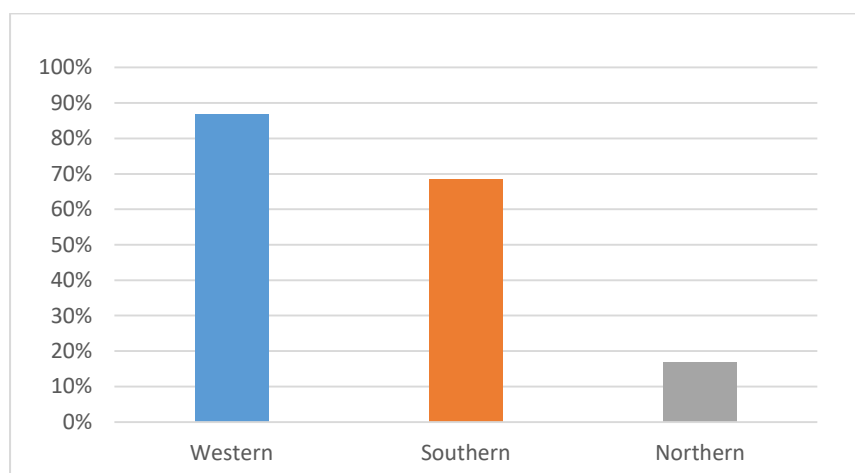
Source: Australian Crop Forecasters (ACF), Supply and Demand Report

There are two main logistical methods of exporting grain—bulk and non-bulk (bags and containers). Bulk handling of grains remains the predominant method of transporting export grain. From 2011-12 to 2015-16, 88% of total wheat exports were transported by bulk handling, with the remaining 12% of wheat exports being transported via containers.

Barley is the second largest exported grain. Australia supplies around 30 to 40% of the world's exported malting barley and 20% of global feed barley (AEGIC, 2019). As observed in the previous

chapter, around 58% of the average annual national production of barley is exported (5.5 MMT). As with wheat, the export profile for barley varies between each region. The western region is the largest exporter of barley in Australia. An annual average of 2.6 MMT of barley was exported from the western region, representing 87% of average annual production. Around 40% of the export volume in the region is malting grade that is destined for China, with the remaining 60% being delivered as feed grade to the Middle East as well as China (GRDC, 2018c). In the southern region, this amount was 2.5 MMT, representing 69% of average annual production. The northern region on the other hand, only exports 0.3 MMT of its average annual production, representing a minor proportion of total barley production (17%). This is mainly due to Qld not producing enough barley to meet its domestic needs.

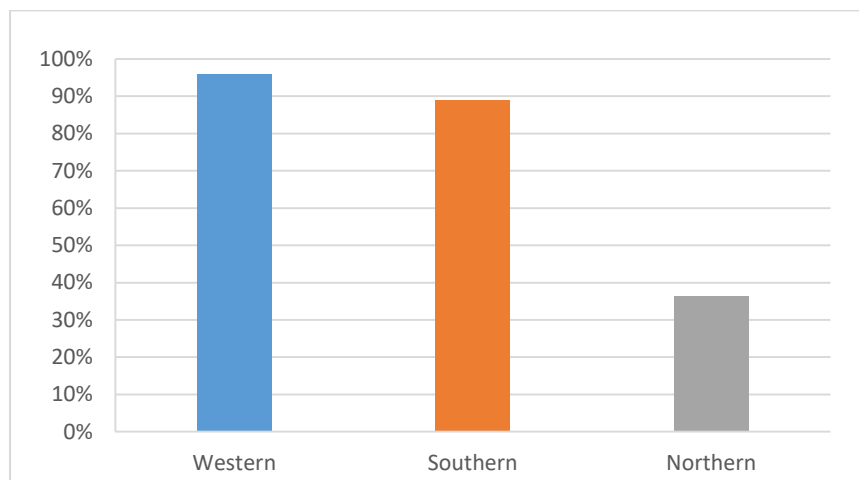
Figure 4.10 Annual average exported barley as a proportion of total production (%), by cropping region 2011-12 to 2015-16



Source: Australian Crop Forecasters (ACF), Supply and Demand Report

Canola exports averaged 2.7 MMT per annum from 2011-12 to 2015-16, representing 78% of the average annual production. The western and southern regions are the main export contributors, shipping an annual average of 1.4 MMT (96% of average annual production) and 0.9 MMT (89% of average annual production) respectively.

Figure 4.11 Annual average exported canola as a proportion of total production (%), by cropping region 2011-12 to 2015-16



Source: Australian Crop Forecasters (ACF), Supply and Demand Report

Domestic Market

The Australian grains industry produces sufficient amounts of grain to satisfy its domestic needs, with the majority of production volume being exported. However, each cropping region allocates different proportions of its total grain production towards domestic use.

The western region is export oriented and only directs a small proportion of its grain production towards the domestic market. From 2011-12 to 2015-16, only 7% of average annual wheat production in the region was allocated to domestic use. For barley, this proportion was 15% and for canola only 4%.

The southern and northern regions divert greater proportions of their grain production towards domestic use, due to high demand from their stockfeed and milling industries.

Processed Grain Products

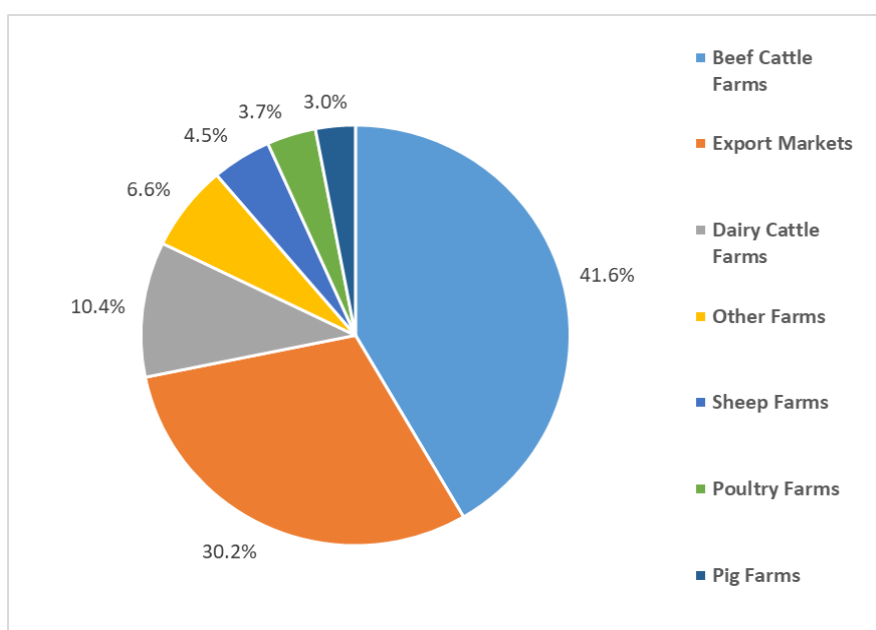
After undergoing secondary processing, raw grains are transformed into grain products. These grain products are either exported or distributed domestically.

The export of flour comprises a very minor portion of total flour production. As shown in Figure 4.6, it is estimated that exports comprise close to only 1% of total flour production. The vast majority of flour is distributed in the domestic markets for human consumption and industrial use.

There is limited information on the distribution of stockfeed. Information is however available on the breakdown of revenue within the sector. Based on IBISWorld (2019), export markets accounted for an estimated 30% of revenue within the sector in 2017-18 (see Figure 4.12). This figure is used in this study as a proxy for the proportion of stockfeed that is distributed to the export markets, with the remaining 70% being distributed to domestic markets.

It is estimated that around 0.7 MMT out of a total 0.9 MMT of malt production is exported, representing around 78% of total production.

Figure 4.12 Breakdown of Farm Animal Feed Production Sector Revenue, 2017-18



Source: IBISWorld, Farm Animal Feed Production in Australia

4.4.4 Interstate Movements

Interstate grain movements occur in order for surplus production in certain States to accommodate the domestic use needs of other States that do not produce enough grain.

NSW has historically been the main net supplier of grain to other states in Australia. Tables 4.2 to 4.4 provide in matrix form, estimates of the annual inflows and outflows of wheat, barley and canola respectively between each State over the period 2011-12 to 2015-16. An annual average of over 2 MMT of wheat from NSW flowed into other States over this period, the majority of which entered into Victoria (1.1 MMT) and Qld (0.8 MMT). An annual average of close to 0.7 MMT of barley flowed

from NSW into Qld and Vic, and for canola, an average of around 0.2 MMT flowed from NSW into Vic annually.

Table 4.2 Average annual Interstate movements of wheat (metric tonnes), 2011-12 to 2015-16

	QLD	NSW	VIC	SA	WA
QLD		-820,000			
NSW	820,000		1,108,000	110,000	
VIC		-1,108,000		-20,000	
SA		-110,000	20,000		-
WA					

Source: Australian Crop Forecasters (ACF), Supply and Demand Reports 2011-12 to 2015-16

Table 4.3 Average annual Interstate movements of barley (metric tonnes), 2011-12 to 2015-16

	QLD	NSW	VIC	SA	WA
QLD		-409,000	0	0	0
NSW	409,000		263,000	0	0
VIC	0	-263,000		-1,500	0
SA	0	0	1,500		0
WA	0	0	0	0	

Source: Australian Crop Forecasters (ACF), Supply and Demand Reports 2011-12 to 2015-16

Table 4.4 Average annual Interstate movements of canola (metric tonnes), 2011-12 to 2015-16

	QLD	NSW	VIC	SA	WA
QLD		0	0	0	0
NSW	0		204,000	4,000	0
VIC	0	-204,000		14,000	0
SA	0	-4,000	-14,000		0
WA	0	0	0	0	

Source: Australian Crop Forecasters (ACF), Supply and Demand Reports 2011-12 to 2015-16

4.5 Summary

Modelling the Australian grains industry is made difficult by vastness in scope and conceptual complexities of the industry. This chapter addresses various conceptual issues in modelling the Australian grains industry and reviews much of the data used in calibrating the EDM in this study.

To overcome the complexity of dynamics inherent in cropping rotations, a steady-state synopsis is generated by assuming that each phase of a rotation sequence is present during each year, allowing the problem to be examined using a comparative static EDM framework.

The entire industry is represented by three distinct and non-overlapping EDMs, with each regional EDM assumed to follow a four crop rotation sequence that is particular to its own region. A review of industry data is provided which highlights the uniqueness of the production and distribution mix of each region. The western and southern regions are predominately export oriented, whereas the northern region is predominantly domestic oriented.

Chapter 5 Model Specification

5.1 Introduction

This chapter specifies the Australian grains industry in equilibrium displacement form. The conceptual structure of each regional model is presented in Section 5.2, along with a discussion on how the model is horizontally and vertically disaggregated. Section 5.3 specifies all the production, cost and revenue functions for the various industry sectors in each regional EDM in general functional form. The general functional form equations of the models are specified in Section 5.4. The model system in equilibrium displacement form is subsequently derived and outlined in Appendix A. The final form of the model with integrability conditions imposed is specified in Appendix B. The notations used in defining the market variables and parameters in each regional EDM are outlined in Tables 5.1 to 5.3 below.

5.2 Model Structure

5.2.1 Western Region

The western region grains industry consists of several market segments along a supply chain. The majority of grain destined for export is first transported from farm to storage at upcountry receival sites. This reduces the risk and cost to producers of storing grain on-farm. From the country receival sites, the grain is either transported to a port terminal for shipping or to various domestic destinations for secondary processing. In WA, Cooperative Bulk Handling (CBH) is the main grain handler, owning a network of 197 receival points that receive and store around 90 to 95 per cent of the grain produced by in the State. CBH also operates all four main bulk grain port terminals in WA (Stretch *et al.*, 2014). Bunge operates an additional small port terminal at Bunbury.

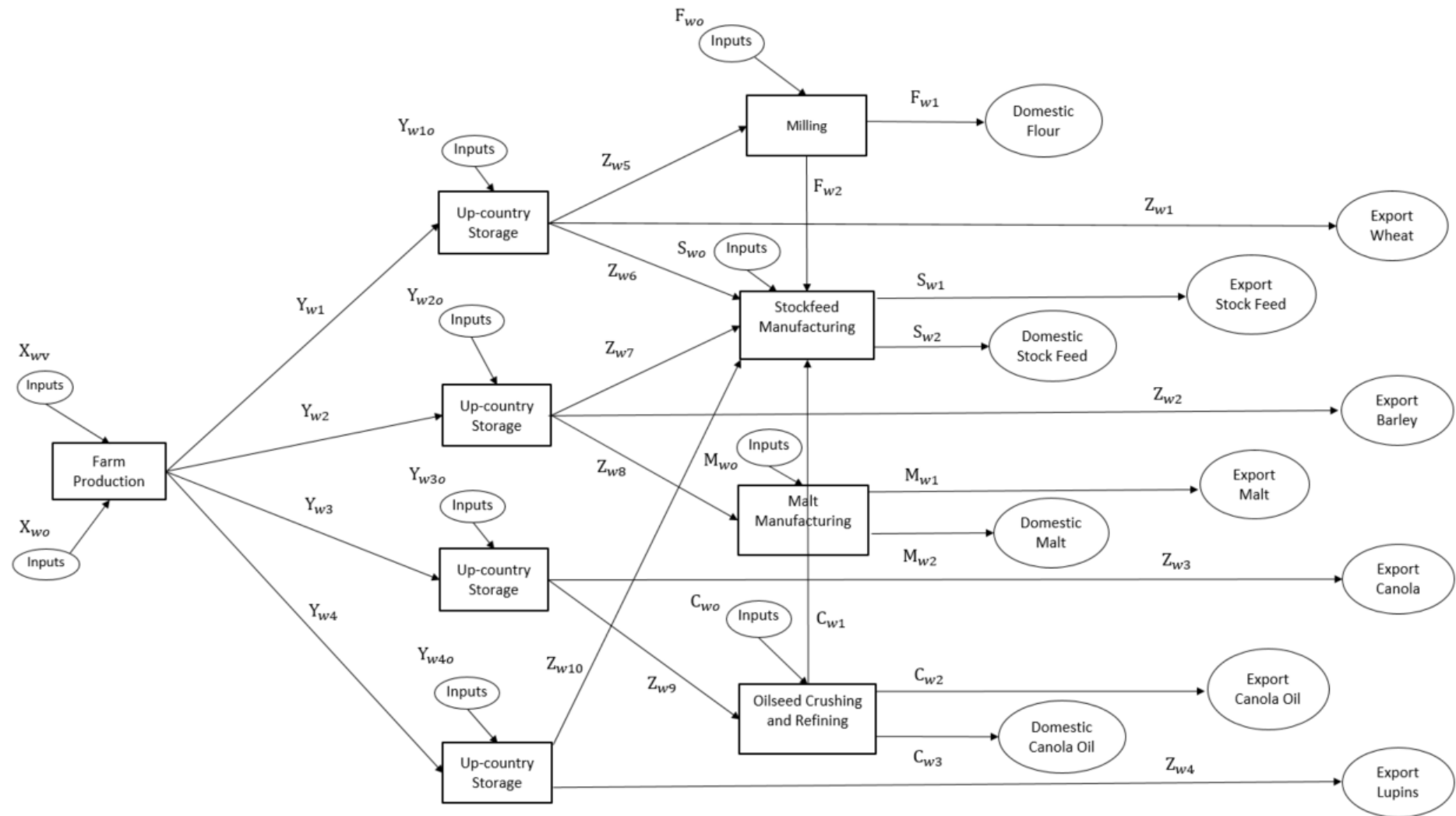
The structure of the western region EDM is depicted in Figure 5.1. Each rectangle represents a multi-output production function. Each arrow represents the market for a product, with the arrowed end being the demand for a product, and the non-arrowed end being the supply of the product. Each oval represents the supply and demand schedule of a product where an exogenous shift may occur.

To study the returns from new technologies and methods brought about by RD&E, as well as the distribution of benefits among the various sectors, vertical and horizontal industry disaggregation is required.

Horizontally, each industry sector along the vertical chain produces a number of different outputs. At the upstream level, farm production is modelled as producing the four grain commodities representative of a standard cropping sequence. The model assumes that all grain from farm production is received and stored up-country, which is the traditional method by which grain is transported (White *et al.*, 2018). It is worth noting however, that on-farm storage is becoming more prominent over the years (White *et al.*, 2018). At the storage and handling stage, grains are either exported or sent for secondary processing, through which multiple end products are produced for either export or domestic use.

Vertically, the industry supply chain is disaggregated into farm production, storage, processing (milling, stockfeed manufacturing, malt manufacturing, oilseed crushing and refining), and consumption.

Figure 5.1 Model Structure of the Western Region EDM

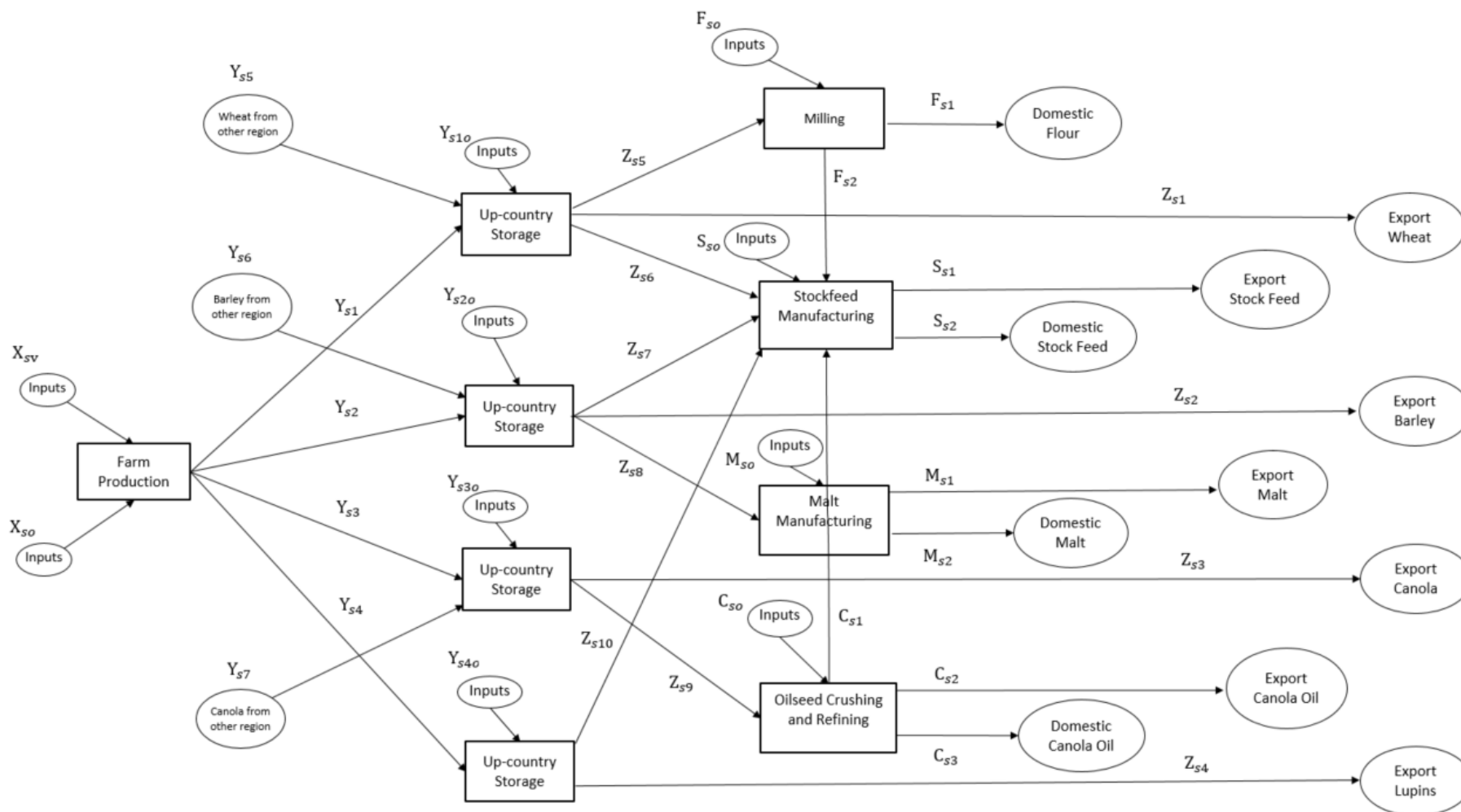


5.2.2 Southern Region

The southern region is modelled to consist of the same market segments along the supply chain as for the western region. Several grain handlers operate in the southern region, the larger of which include Viterro, Emerald and GrainCorp. Viterro is the main handler of grain in SA owning 89 receival sites in the State that represents an 80 per cent market of all up-country grain storage in the State. Viterro also owns all six of the bulk grain ports in SA. In Vic, there is greater competition in grain handling, with several key bulk handlers sharing the market. The largest of these include Emerald and GrainCorp.

The structure of the southern region EDM is depicted in Figure 5.2. The horizontal and vertical industry structure is identical to the western region EDM, with the exception of interstate inflows of grain that are more prominent in the southern region. In this model, it is assumed that wheat, barley and canola from the northern region flows into the southern region via up-country storage facilities before being transported to secondary processing.

Figure 5.2 Model Structure of the Southern Region EDM

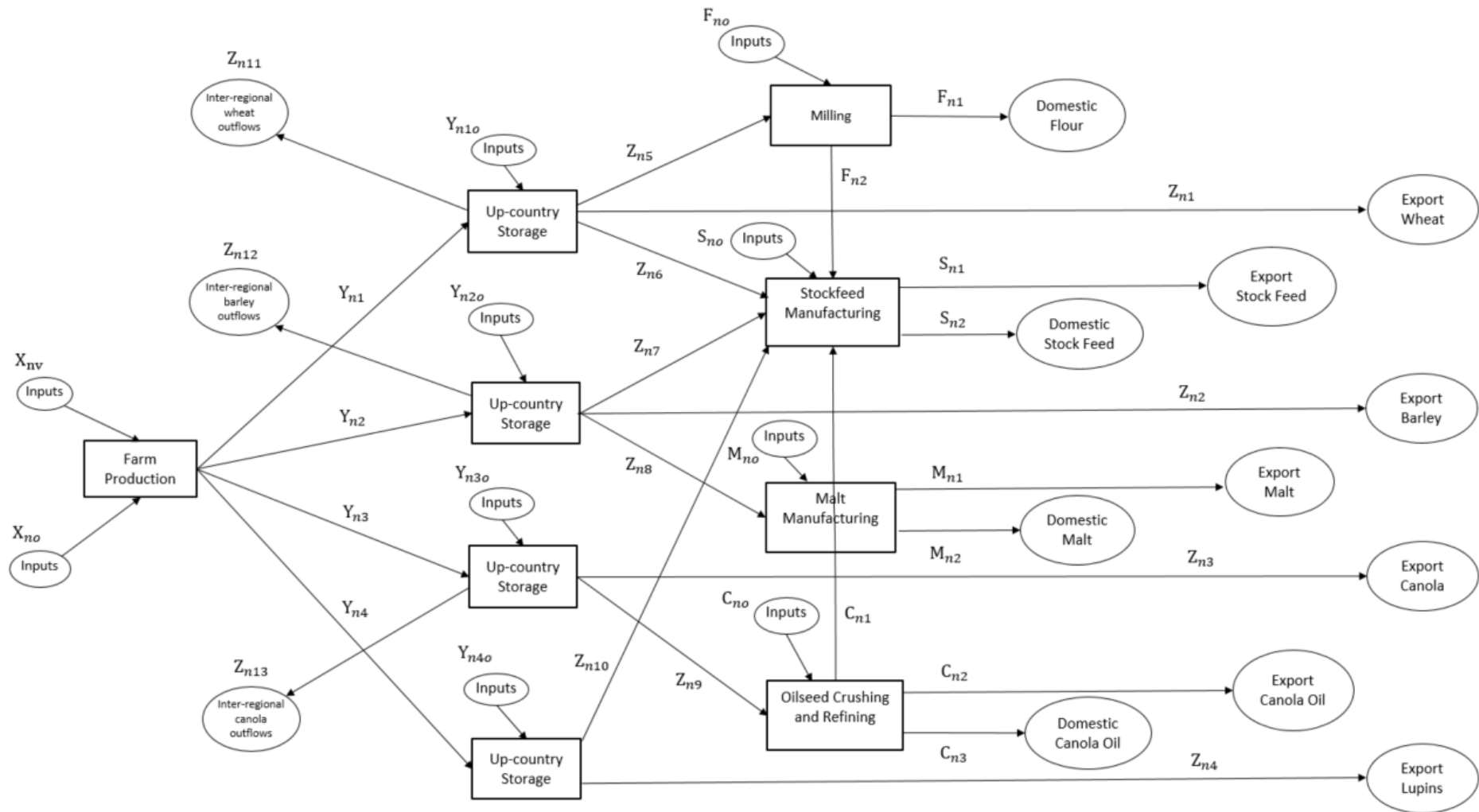


5.2.3 Northern Region

The northern region consists of the same market segments as the western and southern regions. GrainCorp dominates the grain handling activities, owning the region's largest receival network including five bulk grain ports.

The structure of the northern region EDM is depicted in Figure 3. The industry is horizontally and vertically disaggregated in the same manner as the western and southern regions. Outflows of grains from the region are also captured in this model, where it is assumed that wheat, barley and canola from the northern region flows outwards to the southern region from up-country storage

Figure 5.3 Model Structure of the Northern Region EDM



5.2.4 Definition of Variables and Parameters

This section provides a definition of all notation used to define the variables and parameters used in the three EDM models. Tables 5.1 to 5.3 list the variables and parameters that comprise each region's EDM and contain brief descriptions of each variable and parameter. Quantity variables are denoted by upper case letters, whereas prices variables are denoted using lower case letters. In most instances, the subscripts w , s and n are used to differentiate between comparable variables in the Western, Southern and Northern Regions respectively. For instance, the notations Y_{w1} , Y_{s1} and Y_{n1} are used to define the quantity of wheat produced by the farm sector in each region, and v_{w1} , v_{s1} and v_{n1} denote their corresponding prices. Where a variable is referred in general terms during discussions, the subscript is removed, i.e. Y_1 is used when referring to the quantity of wheat in the context of all regions.

Table 5.1 Definition of variables and parameters in the Western Region model

<u>Endogenous Variables</u>	
X_{wv}, X_{wo}	Quantity of variable and fixed inputs used in farm sector, respectively
w_{wv}, w_{wo}	Price of variable and fixed inputs used in farm sector
X^w	Aggregate input index of farm production sector
$Y_{w1}, Y_{w2}, Y_{w3}, Y_{w4}$	Quantity of wheat, barley, canola and lupins from farm to the storage sector
$v_{w1}, v_{w2}, v_{w3}, v_{w4}$	Price of wheat, barley, canola and lupins from farm to the storage sector
Y^w	Aggregate output index of farm production sector
Y_{w1o}	Quantity of other inputs used in wheat storage
v_{w1o}	Price of other inputs used in the wheat storage
Y^{ww}	Aggregate input index of wheat storage
Y_{w2o}	Quantity of other inputs used in barley storage
v_{w2o}	Price of other inputs used in the barley storage
Y^{wb}	Aggregate input index of barley storage
Y_{w3o}	Quantity of other inputs used in canola storage
v_{w3o}	Price of other inputs used in the canola storage
Y^{wc}	Aggregate input index of canola storage
Y_{w4o}	Quantity of other inputs used in lupin storage
v_{w4o}	Price of other inputs used in the lupin storage
Y^{wl}	Aggregate input index of lupin storage
Z_{w1}	Quantity of wheat from wheat storage to export market
Z_{w2}	Quantity of barley from barley storage to export market
Z_{w3}	Quantity of canola from canola storage to export market
Z_{w4}	Quantity of lupins from lupin storage to export market
Z_{w5}, Z_{w6}	Quantity of wheat from storage to flour milling and stock feedback manufacturing, respectively
Z_{w7}, Z_{w8}	Quantity of barley from storage to stockfeed manufacturing and malt manufacturing respectively
Z_{w9}	Quantity of canola from storage to canola processing
Z_{w10}	Quantity of lupins from storage to stockfeed manufacturing
u_{w1}	Price of wheat from wheat storage to the export market
u_{w2}	Price of barley from barley storage to the export market
u_{w3}	Price of canola from canola storage to the export market
u_{w4}	Price of lupins from lupin storage to the export market
u_{w5}, u_{w6}	Price of wheat from storage to flour milling and stock feedback, respectively
u_{w7}, u_{w8}	Price of barley from storage to stockfeed manufacturing and malt manufacturing respectively
u_{w9}	Price of canola from storage to canola processing
u_{w10}	Price of lupins from storage to stockfeed manufacturing
Z^{ww}	Aggregate output index of wheat storage
Z^{wb}	Aggregate output index of barley storage
Z^{wc}	Aggregate output index of canola storage
Z^{wl}	Aggregate output index of lupin storage
F_{wo}	Quantity of other inputs used in flour milling

g_{wo}	Price of other inputs used in flour milling
Z^{wf}	Aggregate input index of flour milling
F_{w1}	Quantity of flour from flour milling to domestic market
g_{w1}	Price of flour to domestic market
F_{w2}	Quantity of Millmix from flour milling to Stockfeed Manufacturing
g_{w2}	Price of Millmix from flour milling to Stockfeed Manufacturing
F^w	Aggregate output index of flour milling
S_{wo}	Quantity of other inputs used in stockfeed manufacturing
t_{wo}	Price of other inputs used in stockfeed manufacturing
Z^{ws}	Aggregate input index of stockfeed manufacturing
S_{w1}, S_{w2}	Quantity of stockfeed to Export and Domestic market, respectively
t_{w1}, t_{w2}	Price of stockfeed to Export and Domestic market, respectively
S^w	Aggregate output index of stockfeed manufacturing
M_{wo}	Quantity of other inputs used in malt manufacturing
n_{wo}	Price of other inputs used in malt manufacturing
Z^{wm}	Aggregate input index of malt manufacturing
M_{w1}, M_{w2}	Quantity of malt to export and domestic market, respectively
n_{w1}, n_{w2}	Price of malt to export and domestic market, respectively
M^w	Aggregate output index of malt manufacturing
C_{wo}	Quantity of other inputs used in Canola processing
d_{wo}	Price of other inputs used in Canola processing
Z^{wc}	Aggregate input index of canola processing
C_{w1}	Quantity of canola meal to stockfeed manufacturing
d_{w1}	Price of canola meal to stockfeed manufacturing
C_{w2}, C_{w3}	Quantity of canola oil to export and domestic market, respectively
d_{w2}, d_{w3}	Prices of canola oil to export and domestic market, respectively
C^w	Aggregate output index of canola processing sector

Exogenous Variables

T_x :	Supply shifter shifting down supply curve of x vertically due to cost reduction in production of x ($x = X_{wo}, X_{wv}, Y_{w1o}, Y_{w2o}, Y_{w3o}, Y_{w4o}, F_{wo}, S_{wo}, M_{wo}, C_{wo}$).
t_x :	Amount of shift T_x as a percentage of price x ($x = X_{wo}, X_{wv}, Y_{w1o}, Y_{w2o}, Y_{w3o}, Y_{w4o}, F_{wo}, S_{wo}, M_{wo}, C_{wo}$).
N_x :	Demand shifter shifting up demand curve of x vertically due to improvements in quality or promotion that increase the demand in x ($x = Z_{w1}, Z_{w2}, Z_{w3}, Z_{w4}, F_{w1}, S_{w1}, S_{w2}, M_{w1}, M_{w2}, C_{w2}, C_{w3}$).
n_x :	Amount of shift N_x as a percentage of price of x ($x = Z_{w1}, Z_{w2}, Z_{w3}, Z_{w4}, F_{w1}, S_{w1}, S_{w2}, M_{w1}, M_{w2}, C_{w2}, C_{w3}$).

Parameters

$\eta_{i,j}$	Demand elasticity of input i with respect to price j

$\varepsilon_{i,j}$	Supply elasticity of input i with respect to price j
$\tilde{\eta}_{i,j}$	Constant-output input demand elasticity of input i with respect to price j
$\tilde{\varepsilon}_{i,j}$	Constant-input output supply elasticity of input 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

Table 5.2 Definition of variables and parameters in the Southern Region model

<u>Endogenous Variables</u>	
X_{sv}, X_{so}	Quantity of variable and fixed inputs used in farm sector, respectively
w_{sv}, w_{so}	Price of variable and fixed inputs used in farm sector
X^s	Aggregate input index of farm production sector
$Y_{s1}, Y_{s2}, Y_{s3}, Y_{s4}$	Quantity of wheat, barley, canola and peas from farm to the storage sector
$v_{s1}, v_{s2}, v_{s3}, v_{s4}$	Price of wheat, barley, canola and peas from farm to the storage sector
Y^s	Aggregate output index of farm production sector
Y_{s10}	Quantity of other inputs used in wheat storage
v_{s10}	Price of other inputs used in wheat storage
Y_{s5}	Quantity of inter-regional wheat inflows to wheat storage
v_{s5}	Price of inter-regional wheat inflows to wheat storage
Y^{sw}	Aggregate input index of wheat storage
Y_{s20}	Quantity of other inputs used in barley storage sector
v_{s20}	Price of other inputs used in the barley storage sector
Y_{s6}	Quantity of inter-regional barley inflows to wheat storage
v_{s6}	Price of inter-regional barley inflows to wheat storage
Y^{sb}	Aggregate input index of barley storage
Y_{s30}	Quantity of other inputs used in canola storage sector
v_{s30}	Price of other inputs used in canola storage sector
Y_{s7}	Quantity of inter-regional canola inflows to wheat storage
v_{s7}	Price of inter-regional canola inflows to wheat storage
Y^{sc}	Aggregate input index of canola storage
Y_{s40}	Quantity of other inputs used in pea storage sector
v_{s40}	Price of other inputs used in pea storage sector
Y^{sp}	Aggregate input index of pea storage
Z_{s1}	Quantity of wheat from wheat storage to the export market
Z_{s2}	Quantity of barley from barley storage to the export market
Z_{s3}	Quantity of canola from canola storage to the export market
Z_{s4}	Quantity of peas from pea storage to the export market
Z_{s5}, Z_{s6}	Quantity of wheat from storage to flour milling and stock feedback manufacturing, respectively
Z_{s7}, Z_{s8}	Quantity of barley from storage to stockfeed manufacturing and malt manufacturing respectively
Z_{s9}	Quantity of canola from storage to canola processing
Z_{s10}	Quantity of peas from storage to stockfeed manufacturing
u_{s1}	Price of wheat from wheat storage to the export market
u_{s2}	Price of barley from barley storage to the export market
u_{s3}	Price of canola from canola storage to the export market
u_{s4}	Price of peas from pea storage to the export market
u_{s5}, u_{s6}	Price of wheat from storage to flour milling and stock feedback, respectively
u_{s7}, u_{s8}	Price of barley from storage to stockfeed manufacturing and malt manufacturing respectively

u_{s9}	Price of canola from storage to canola processing
u_{s10}	Price of peas from storage to stockfeed manufacturing
Z^{sw}	Aggregate output index of wheat storage
Z^{sb}	Aggregate output index of barley storage
Z^{sc}	Aggregate output index of canola storage
Z^{sl}	Aggregate output index of pea storage
F_{so}	Quantity of other inputs used in flour milling
g_{so}	Price of other inputs used in flour milling
Z^{sf}	Aggregate input index of flour milling
F_{s1}	Quantity of flour from flour milling to domestic market
g_{s1}	Price of flour to domestic market
F_{s2}	Quantity of Millmix from flour milling to Stockfeed Manufacturing
g_{s2}	Price of Millmix from flour milling to Stockfeed Manufacturing
F^s	Aggregate output index of flour milling
S_{so}	Quantity of other inputs used in stockfeed manufacturing
t_{so}	Price of other inputs used in stockfeed manufacturing
Z^{ss}	Aggregate input index of stockfeed manufacturing
S_{s1}, S_{s2}	Quantity of stockfeed to Export and Domestic market, respectively
t_{s1}, t_{s1}	Price of stockfeed to Export and Domestic market, respectively
S^s	Aggregate output index of stockfeed manufacturing
M_{so}	Quantity of other inputs used in malt manufacturing
n_{so}	Price of other inputs used in malt manufacturing
Z^{sm}	Aggregate input index of malt manufacturing
M_{s1}, M_{s2}	Quantity of malt to export and domestic market, respectively
n_{s1}, n_{s2}	Price of malt to export and domestic market, respectively
M^s	Aggregate output index of malt manufacturing
C_{so}	Quantity of other inputs used in Canola processing
d_{so}	Price of other inputs used in Canola processing
Z^{sc}	Aggregate input index of canola processing
C_{s1}	Quantity of canola meal to stockfeed manufacturing
d_{s1}	Price of canola meal to stockfeed manufacturing
C_{s2}, C_{s3}	Quantity of canola oil to export and domestic market, respectively
d_{s2}, d_{s3}	Prices of canola oil to export and domestic market, respectively
C^s	Aggregate output index of canola processing sector

Exogenous Variables

T_x :	Supply shifter shifting down supply curve of x vertically due to cost reduction in production of x ($x = X_{so}, X_{sv}, Y_{s10}, Y_{s20}, Y_{s30}, Y_{s40}, Y_{s5}, Y_{s6}, Y_{s7}, F_{so}, S_{so}, M_{so}, C_{so}$).
t_x :	Amount of shift T_x as a percentage of price x ($x = X_{so}, X_{sv}, Y_{s10}, Y_{s20}, Y_{s30}, Y_{s40}, Y_{s5}, Y_{s6}, Y_{s7}, F_{so}, S_{so}, M_{so}, C_{so}$).
N_x :	Demand shifter shifting up demand curve of x vertically due to improvements in quality or promotion that increase the demand in x ($x = Z_{s1}, Z_{s2}, Z_{s3}, Z_{s4}, F_{s1}, S_{s1}, S_{s2}, M_{s1}, M_{s2}, C_{s2}, C_{s3}$).

n_x : Amount of shift N_x as a percentage of price of x
 ($x = Z_{s1}, Z_{s2}, Z_{s3}, Z_{s4}, F_{s1}, S_{s1}, S_{s2}, M_{s1}, M_{s2}, C_{s2}, C_{s3}$).

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

Table 5.3 Definition of variables and parameters in the Northern Region model

<u>Endogenous Variables</u>	
X_{nv}, X_{no}	Quantity of variable and fixed inputs used in farm sector, respectively
w_{nv}, w_{no}	Price of variable and fixed used in farm sector
X^n	Aggregate input index of farm production sector
$Y_{n1}, Y_{n2}, Y_{n3}, Y_{n4}$	Quantity of wheat, barley, canola and chickpeas from farm to the storage sector
$v_{n1}, v_{n2}, v_{n3}, v_{n4}$	Price of wheat, barley, canola and chickpeas from farm to the storage sector
Y^n	Aggregate output index of farm production sector
Y_{n1o}	Quantity of other inputs used in wheat storage sector
v_{n1o}	Price of other inputs used in wheat storage sector
Y^{nw}	Aggregate input index of wheat storage
Y_{n2o}	Quantity of other inputs used in wheat storage sector
v_{n2o}	Price of other inputs used in the wheat storage sector
Y^{nb}	Aggregate input index of barley storage
Y_{n3o}	Quantity of other inputs used in canola storage sector
v_{n3o}	Price of other inputs used in the canola storage sector
Y^{nc}	Aggregate input index of canola storage
Y_{n4o}	Quantity of other inputs used in chickpea storage sector
v_{n4o}	Price of other inputs used in the chickpea storage sector
Y^{nh}	Aggregate input index of chickpea storage sector
Z_{n1}	Quantity of wheat from wheat storage to the export market
Z_{n2}	Quantity of barley from barley storage to the export market
Z_{n3}	Quantity of canola from canola storage to the export market
Z_{n4}	Quantity of chickpeas from chickpea storage to the export market
Z_{n5}, Z_{n6}	Quantity of wheat from storage to flour milling and stock feedback manufacturing, respectively
Z_{n7}, Z_{n8}	Quantity of barley from storage to stockfeed manufacturing and malt manufacturing respectively
Z_{n9}	Quantity of canola from storage to canola processing
Z_{n10}	Quantity of chickpeas from storage to stockfeed manufacturing
$Z_{n11}, Z_{n12}, Z_{n13}$	Quantity of wheat, barley and canola outflows to other cropping regions
u_{n1}	Price of wheat from wheat storage to the export market
u_{n2}	Price of barley from barley storage to the export market
u_{n3}	Price of canola from canola storage to the export market
u_{n4}	Price of chickpeas from chickpea storage to the export market
u_{n5}, u_{n6}	Price of wheat from storage to flour milling and stock feedback, respectively
u_{n7}, u_{n8}	Price of barley from storage to stockfeed manufacturing and malt manufacturing respectively
u_{n9}	Price of canola from storage to canola processing
u_{n10}	Price of chickpeas from storage to stockfeed manufacturing
$u_{n11}, u_{n12}, u_{n13}$	Price of wheat, barley and canola outflows to other cropping regions
Z^{nw}	Aggregate output index of wheat storage

Z^{nb}	Aggregate output index of barley storage
Z^{nc}	Aggregate output index of canola storage
Z^{nl}	Aggregate output index of pea storage
F_{no}	Quantity of other inputs used in flour milling
g_{no}	Price of other inputs used in flour milling
Z^{nf}	Aggregate input index of flour milling
F_{n1}	Quantity of flour from flour milling to domestic market
g_{n1}	Price of flour to domestic market
F_{n2}	Quantity of Millmix from flour milling to Stockfeed Manufacturing
g_{n2}	Price of Millmix from flour milling to Stockfeed Manufacturing
F^n	Aggregate output index of flour milling
S_{no}	Quantity of other inputs used in stockfeed manufacturing
t_{no}	Price of other inputs used in stockfeed manufacturing
Z^{ns}	Aggregate input index of stockfeed manufacturing
S_{n1}, S_{n2}	Quantity of stockfeed to Export and Domestic market, respectively
t_{n1}, t_{n2}	Price of stockfeed to Export and Domestic market, respectively
S^n	Aggregate output index of stockfeed manufacturing
M_{no}	Quantity of other inputs used in malt manufacturing
n_{no}	Price of other inputs used in malt manufacturing
Z^{nm}	Aggregate input index of malt manufacturing
M_{n1}, M_{n2}	Quantity of malt to export and domestic market, respectively
n_{n1}, n_{n2}	Price of malt to export and domestic market, respectively
M^n	Aggregate output index of malt manufacturing
C_{no}	Quantity of other inputs used in Canola processing
d_{no}	Price of other inputs used in Canola processing
Z^{nc}	Aggregate input index of canola processing
C_{n1}	Quantity of canola meal to stockfeed manufacturing
d_{n1}	Price of canola meal to stockfeed manufacturing
C_{n2}, C_{n3}	Quantity of canola oil to export and domestic market, respectively
d_{n2}, d_{n3}	Prices of canola oil to export and domestic market, respectively
C^n	Aggregate output index of canola processing sector
<u>Exogenous Variables</u>	
T_x :	Supply shifter shifting down supply curve of x vertically due to cost reduction in production of x ($x = X_{no}, X_{nv}, Y_{n1o}, Y_{n2o}, Y_{n3o}, Y_{n4o}, F_{no}, S_{no}, M_{no}, C_{no}$).
t_x :	Amount of shift T_x as a percentage of price x ($x = X_{no}, X_{nv}, Y_{n1o}, Y_{n2o}, Y_{n3o}, Y_{n4o}, F_{no}, S_{no}, M_{no}, C_{no}$).
N_x :	Demand shifter shifting up demand curve of x vertically due to improvements in quality or promotion that increase the demand in x ($x = Z_{n1}, Z_{n2}, Z_{n3}, Z_{n4}, Z_{11}, Z_{12}, Z_{13}, F_{n1}, S_{n1}, S_{n2}, M_{n1}, M_{n2}, C_{n2}, C_{n3}$).
n_x :	Amount of shift N_x as a percentage of price of x ($x = Z_{n1}, Z_{n2}, Z_{n3}, Z_{n4}, Z_{11}, Z_{12}, Z_{13}, F_{n1}, S_{n1}, S_{n2}, M_{n1}, M_{n2}, C_{n2}, C_{n3}$).

<u>Parameters</u>	
$\eta_{i,j}$	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

5.3 Model Specification

The equations for the model follow the specifications of Zhao *et al.* (2000b) and Mounter *et al.* (2004). 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 market within the model. Perfect competition is assumed for each market of the industry's supply chain. This means that under the assumption of constant returns to scale, total costs must equal total revenue for each industry sector (zero pure profits). The equilibrium equations describing this condition are outlined for each region in the following subsections.

5.3.1 Western Region

Figure 5.1 displays the nine industry sectors (farm production, up-country wheat storage, up-country barley storage, up-country canola storage, up-country lupin storage, milling, stockfeed manufacturing, malt manufacturing, and oilseed crushing and refining) whose multi-output production functions and decision making problems can be specified completely within the model. The following equilibrium conditions apply whereby total costs equate to total revenue for each industry market

(5.3.1) $\sum_{i=v,o} w_{wi} X_{wi} = \sum_{i=1,2,3,4} v_{wi} Y_{wi}$	<i>farm production equilibrium</i>
(5.3.2) $v_{w1} Y_{w1} + v_{w1o} Y_{w1o} = \sum_{i=1,5,6} u_{wi} Z_{wi}$	<i>wheat storage equilibrium</i>
(5.3.3) $v_{w2} Y_{w2} + v_{w2o} Y_{w2o} = \sum_{i=2,7,8} u_{wi} Z_{wi}$	<i>barley storage equilibrium</i>
(5.3.4) $v_{w3} Y_{w3} + v_{w3o} Y_{w3o} = \sum_{i=3,9} u_{wi} Z_{wi}$	<i>canola storage equilibrium</i>
(5.3.5) $v_{w4} Y_{w4} + v_{w4o} Y_{w4o} = \sum_{i=4,10} u_{wi} Z_{wi}$	<i>lupin storage equilibrium</i>
(5.3.6) $u_{w5} Z_{w5} + g_{wo} F_{wo} = \sum_{i=1,2} g_{wi} F_{wi}$	<i>milling equilibrium</i>
(5.3.7) $\sum_{i=6,7,10} u_{wi} Z_{wi} + g_{w2} F_{w2} + d_{w1} C_{w1} + t_{wo} S_{wo}$ $= \sum_{i=1,2} t_{wi} S_{wi}$	<i>stockfeed manufacturing equilibrium</i>
(5.3.8) $u_{w8} Z_{w8} + n_{wo} M_{wo} = \sum_{i=1,2} n_{wi} M_{wi}$	<i>malt manufacturing equilibrium</i>
(5.3.9) $u_{w9} Z_{w9} + d_{wo} C_{wo} = \sum_{i=1,2,3} d_{wi} C_{wi}$	<i>oilseed crushing and refining equilibrium</i>

For each of the above industry market equilibrium conditions, total costs are represented on the left hand side and total revenue on the right hand side. The cost shares of other non-grain inputs particular to each market ($w_{wv}, w_{wo}, Y_{w1o}, Y_{w2o}, Y_{w3o}, Y_{w4o}, F_{wo}, S_{wo}, M_{wo}, C_{wo}$) are calculated as the residual for each equilibrium condition above.

Production Functions

As shown in Figure 5.1, the farm, up-country storage, milling, stockfeed manufacturing, malt manufacturing and oilseed crushing and refining sectors are characterised by multi-output production functions. All the production functions are deemed to exhibit constant returns to scale with multi-output production functions separable in inputs and outputs¹. The objective of profit maximisation is an implicit behavioural assumption of each industry sector within the model.

Following Zhao *et al.* (2000b, p.11), the multi-output production function written in general form can be represented as follows:

$$(5.3.10) F(x, y) = 0$$

where x is a vector of inputs and y is a vector of outputs. This product transformation function is assumed to be twice-continuously differentiable.

Taking the farm production sector from the model as an example, $x = (X_{wv}, X_{wo})$ and $y = (Y_{w1}, Y_{w2}, Y_{w3}, Y_{w4})$.

The output separability assumption (Chambers, 1998, p.286) ensures that there exists a scalar output index such that Equation 5.3.10 can be written as:

$$(5.3.11) Y^w(y) = X^w(x)$$

Where $Y^w = Y^w(y)$ is the scalar output index and $X^w = X^w(x)$ is the associated scalar input index. Based on this logic, the product transformation functions for the six industry sectors in the region can be written as follows:

¹ See Chambers (1998) and Varian (1992) for a more detailed explanation of the derivations here

(5.3.12)	$Y^w(Y_{w1}, Y_{w2}, Y_{w3}, Y_{w4}) = X^w(X_{wv}, X_{wo})$	<i>farm production</i>
(5.3.13)	$Z^{ww}(Z_{w1}, Z_{s5}, Z_{s6}) = Y^{ww}(Y_{w1}, Y_{w10})$	<i>wheat storage</i>
(5.3.14)	$Z^{wb}(Z_{w2}, Z_{w7}, Z_{w8}) = Y^{wb}(Y_{w2}, Y_{w20})$	<i>barley storage</i>
(5.3.15)	$Z^{wc}(Z_{w3}, Z_{w9}) = Y^{wc}(Y_{w3}, Y_{w30})$	<i>canola storage</i>
(5.3.16)	$Z^{wl}(Z_{w4}, Z_{w10}) = Y^{wl}(Y_{w4}, Y_{w40})$	<i>lupin storage</i>
(5.3.17)	$F^w(F_{w1}, F_{w2},) = Z^{wf}(Z_{w5}, F_{wo})$	<i>milling</i>
(5.3.18)	$S^w(S_{w1}, S_{w2}) = Z^{ws}(Z_{w6}, Z_{w7}, Z_{w10}, C_{w1}, F_{w2}, S_{wo})$	<i>stockfeed manufacturing</i>
(5.3.19)	$M^w(M_{w1}, M_{w2}) = Z^{wm}(Z_{w8}, M_{wo})$	<i>malt manufacturing</i>
(5.3.20)	$C^w(C_{w1}, C_{w2}, C_{w3}) = Z^{wc}(Z_{w9}, C_{wo})$	<i>oilseed crushing & refining</i>

The variables on the left sides of the equations are outputs for the relevant sectors and the variables on the right sides are the inputs.

Cost Functions and Derived Demand Schedules

As detailed in Zhao *et al.* (2000b p.11), the assumption of profit maximisation implies that the industry's allocation problem can be considered in two parts. The first is cost minimisation for a given level of the output vector. Taking the example of farm production, the cost function can be specified as:

$$(5.3.21) C_{Y^w}(w, y) = \min\{w'x: y\}$$

where $w = (w_{wv}, w_{wo})'$ are the input prices for (X_{wv}, X_{wo}) ,

When technology is assumed to be output separable, the multi-output cost function can be simplified to a single-output cost function as described by Chambers (1998, p.285) and Zhao *et al.*, (2000b, p.11)

$$(5.3.22) C_{Y^w}(w, y) = \min_x\{w'x: y\} = \min_x\{w'x: Y^w = Y^w(y)\} = C_{Y^w}(w, Y^w)$$

where $C_{Y^w}(w, Y^w)$ is the cost function for the single output technology $Y^w = X^w(x)$.

The assumption of constant returns to scale implies that $X^w(nx) = nY^w$ and $Y^w(nx) = nX^w$ for all $n > 0$. Therefore, the cost function can be written as:

$$\begin{aligned}
(5.3.23) \quad C_{Y^w}(w, Y^w) &= \min_x \{w'x: X^w(x) = Y^w\} \\
&= \min_x \{w'x: X^w(nx) = nY^w\} \\
&= \min_x \{w'x: X^w(x/Y^w) = 1\} \quad (\text{when } n = 1/Y^w) \\
&= Y^w \min_x \{w'(x/Y^w): X^w(x/Y^w) = 1\} = Y^w C_{Y^w}(w, 1) = Y^w c_{Y^w}(w)
\end{aligned}$$

where $c_{Y^w}(w)$ is the unit cost function associated with the minimum cost of producing one unit of Y^w .

The general results in Equation 5.3.23 can be used to derive the cost functions related to all the production functions in the region as follows:

$$\begin{aligned}
(5.3.24) \quad C_{Y^w} &= Y^w * c_{Y^w}(w_{wv}, w_{wo}) && \text{farm production} \\
(5.3.25) \quad C_{Z^{ww}} &= Z^{ww} * c_{Z^{ww}}(v_{w1}, v_{w1o}) && \text{wheat storage} \\
(5.3.26) \quad C_{Z^{wb}} &= Z^{wb} * c_{Z^{wb}}(v_{w2}, v_{w2o}) && \text{barley storage} \\
(5.3.27) \quad C_{Z^{wc}} &= Z^{wc} * c_{Z^{wc}}(v_{w3}, v_{w3o}) && \text{canola storage} \\
(5.3.28) \quad C_{Z^{wl}} &= Z^{wl} * c_{Z^{wl}}(v_{w4}, v_{w4o}) && \text{lupin storage} \\
(5.3.29) \quad C_{F^w} &= F^w * c_{F^w}(u_{w5}, g_{wo}) && \text{milling} \\
(5.3.30) \quad C_{S^w} &= S^w * c_{S^w}(u_{w6}, u_{w7}, u_{w10}, d_{w1}, g_{w2}, t_{wo}) && \text{stockfeed manufacturing} \\
(5.3.31) \quad C_{M^w} &= M^w * c_{M^w}(u_{w8}, n_{wo}) && \text{malt manufacturing} \\
(5.3.32) \quad C_{C^w} &= C^w * c_{C^w}(u_{w9}, d_{wo}) && \text{oilseed crushing \& refining}
\end{aligned}$$

where C_x denotes the total cost of producing output index x and c_x stands for the unit cost function, and where $x = Y^w, Z^w, F^w, S^w, M^w$ and C^w . Quantities are represented by capital letters and prices by lower case letters.

The corresponding demand functions can be derived from these cost functions using Shephard's Lemma.

Assume $c_{Y^w}(w)$ is differentiable with respect to w . By applying Shepard's Lemma (Jehle and Reny, 2011, p. 138) we have:

$$(5.3.33) \quad \partial C_{Y^w}(w, Y^w) / \partial w_i = Y^w c_{Y^w}'_i(w) \quad (i = 1, 2, \dots, k)$$

where $c_{Y^w}'_i(w)$, $(i = 1, 2, \dots, k)$ are the partial derivatives of the unit cost function $c_{Y^w}(w)$.

Equation 5.3.33 is used to derive the output constrained input demand functions for all relevant sectors in the model in Section 5.4.1.

Revenue Functions and Derived Supply Schedules

The second part of profit maximisation is to maximise revenue for a given input mix. Taking the example of farm production, the revenue function can be specified as (Zhao *et al.*, 2000b, p.12):

$$(5.3.34) R_{X^w}(v, x) = \max_y \{v'y : x\}$$

Where $v = (v_{w1}, v_{w2}, v_{w3}, v_{w4})'$ are the output prices for (Y_1, Y_2, Y_3, Y_4) .

The assumption of input separability allows Equation 5.3.34 to be expressed in terms of a single input revenue function as (Zhao *et al.*, 2000b, p.12):

$$(5.3.35) R_{X^w}(v, x) = \max_y \{v'y : x\} = \max_y \{v'y : X^w = X^w(x)\} = R_{X^w}(v, X^w)$$

Where $R_{X^w}(v, X^w)$ is the revenue function for the single input technology $X^w = Y^w(y)$.

Constant returns to scale imply that the revenue function can be written as (Zhao *et al.*, 2000b, p.12):

$$\begin{aligned} (5.3.36) R_{X^w}(v, X^w) &= \max_y \{v'y : Y^w(y) = X^w\} \\ &= \max_y \{v'y : Y^w(ny) = nX^w\} \\ &= \max_y \{v'y : Y^w(y/X^w) = 1\} \quad (\text{when } n = 1/X^w) \\ &= X^w \max_y \{v'(y/X^w) : Y^w(y/X^w) = 1\} = X^w R_{X^w}(v, 1) = X^w r_{X^w}(v) \end{aligned}$$

Where $r_{X^w}(v)$ is the unit revenue function associated with the maximum revenue from one unit of input index X^w .

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

(5.3.37)	$R_{X^w} = X^w * r_{X^w}(v_{w1}, v_{w2}, v_{w3}, v_{w4})$	<i>farm production</i>
(5.3.38)	$R_{Y^{ww}} = Y^{ww} * r_{Y^{ww}}(u_{w1}, u_{w5}, u_{w6},)$	<i>wheat storage</i>
(5.3.39)	$R_{Y^{wb}} = Y^{wb} * r_{Y^{wb}}(u_{w2}, u_{w7}, u_{w8},)$	<i>barley storage</i>
(5.3.40)	$R_{Y^{wc}} = Y^{wc} * r_{Y^{wc}}(u_{w3}, u_{w9})$	<i>canola storage</i>
(5.3.41)	$R_{Y^{wl}} = Y^{wl} * r_{Y^{wl}}(u_{w4}, u_{w10})$	<i>lupin storage</i>
(5.3.42)	$R_{Z^{wf}} = Z^{wf} * r_{Z^{wf}}(g_{w1}, g_{w2})$	<i>milling</i>
(5.3.43)	$R_{Z^{ws}} = Z^{ws} * r_{Z^{ws}}(t_{w1}, t_{w2})$	<i>stockfeed manufacturing</i>
(5.3.44)	$R_{Z^{wm}} = Z^{wm} * r_{Z^{wm}}(n_{w1}, n_{w2})$	<i>malt manufacturing</i>
(5.3.45)	$R_{Z^{wc}} = Z^{wc} * r_{Z^{wc}}(d_{w1}, d_{w2}, d_{w3})$	<i>oilseed crushing & refining</i>

where R_x denotes the total revenue generated from the fixed input index x and r_x stands for the unit revenue function. Similarly, quantities are represented by capital letters and prices by lower case letters.

From the revenue function above, if $r_{X^w}(v)$ is differentiable with respect to all output prices, then using the Samuelson-McFadden Lemma (Chambers, 1998, p.264) gives:

$$(5.3.46) \quad \partial R_{X^w}(v, X^w) / \partial v_j = X^w r_{X^w}'_j(v) \quad (j = 1, 2, \dots, m)$$

Where $r_{X^w}'_j(v)$, $(j = 1, 2, \dots, m)$ are the partial derivatives of the unit revenue function $r_{X^w}(v)$.

Equation 5.3.46 is used to derive the input constrained output supply functions for all relevant sectors in the model in Section 5.4.1.

5.3.2 Southern Region

As with the western region, there are six industry sectors in the southern region EDM (farm production, up-country storage, milling, stockfeed manufacturing, malt manufacturing, and oilseed crushing and refining)) whose multi-output production functions and decision making problems can be specified completely within the model.

Under the assumption that total costs equate to total revenue for each industry sector, we have:

(5.3.47) $\sum_{i=v,o} w_{si} X_{si} = \sum_{i=1,2,3,4} v_{si} Y_{si}$	<i>farm production equilibrium</i>
(5.3.48) $v_{s1} Y_{s1} + v_{s10} Y_{s10} = \sum_{i=1,5,6} u_{si} Z_{si}$	<i>wheat storage equilibrium</i>
(5.3.49) $v_{s2} Y_{s2} + v_{s20} Y_{s20} = \sum_{i=2,7,8} u_{si} Z_{si}$	<i>barley storage equilibrium</i>
(5.3.50) $v_{s3} Y_{s3} + v_{s30} Y_{s30} = \sum_{i=3,9} u_{si} Z_{si}$	<i>canola storage equilibrium</i>
(5.3.51) $v_{s4} Y_{s4} + v_{s40} Y_{s40} = \sum_{i=4,10} u_{wi} Z_{wi}$	<i>pea storage equilibrium</i>
(5.3.52) $u_{s5} Z_{s5} + g_{so} F_{so} = \sum_{i=1,2} g_{si} F_{si}$	<i>milling equilibrium</i>
(5.3.53) $\sum_{i=6,7,10} u_{si} Z_{si} + g_{s2} F_{s2} + t_{so} S_{so} = \sum_{i=1,2} t_{si} S_{si}$	<i>stockfeed manufacturing equilibrium</i>
(5.3.54) $u_{s8} Z_{s8} + n_{so} M_{so} = \sum_{i=1,2} n_{si} M_{si}$	<i>malt manufacturing equilibrium</i>
(5.3.55) $u_{s9} Z_{s9} + d_{so} C_{so} = \sum_{i=1,2,3} d_{si} C_{si}$	<i>oilseed crushing and refining equilibrium</i>

Following the logic in Equation 5.3.11, the product transformation functions for these six industry sectors in the region can be written as follows:

(5.3.56) $Y^s(Y_{s1}, Y_{s2}, Y_{s3}, Y_{s4}) = X^s(X_{sv}, X_{so})$	<i>farm production</i>
(5.3.57) $Z^{sw}(Z_{s1}, Z_{s5}, Z_{s6}) = Y^{sw}(Y_{s1}, Y_{s5}, Y_{s10})$	<i>wheat storage</i>
(5.3.58) $Z^{sb}(Z_{s2}, Z_{s7}, Z_{s8}) = Y^{sb}(Y_{s2}, Y_{s6}, Y_{s20})$	<i>barley storage</i>
(5.3.59) $Z^{sc}(Z_{s3}, Z_{s9}) = Y^{sc}(Y_{s3}, Y_{s7}, Y_{s30})$	<i>canola storage</i>
(5.3.60) $Z^{sp}(Z_{s4}, Z_{s10}) = Y^{sp}(Y_{s4}, Y_{s40})$	<i>pea storage</i>
(5.3.61) $F^s(F_{s1}, F_{s2}) = Z^{sf}(Z_{s5}, F_{so})$	<i>milling</i>
(5.3.62) $S^s(S_{s1}, S_{s2}) = Z^{ss}(Z_{s6}, Z_{s7}, Z_{s10}, C_{s1}, F_{s2}, S_{so})$	<i>stockfeed manufacturing</i>
(5.3.63) $M^s(M_{s1}, M_{s2}) = Z^{sm}(Z_{s8}, M_{so})$	<i>malt manufacturing</i>
(5.3.64) $C^s(C_{s1}, C_{s2}, C_{s3}) = Z^{sc}(Z_{s9}, C_{so})$	<i>oilseed crushing & refining</i>

The variables on the left sides of the equations are outputs for the relevant sectors and the variables on the right sides are the inputs.

Following the logic presented in Equation 5.3.23, cost functions related to these production functions are written as:

(5.3.65) $C_{Y^s} = Y^s * c_{Y^s}(w_{sv}, w_{so})$	<i>farm production</i>
(5.3.66) $C_{Z^{sw}} = Z^{sw} * c_{Z^{sw}}(v_{s1}, v_{s5}, v_{s10})$	<i>wheat storage</i>

(5.3.67)	$C_{Zsb} = Z^{sb} * c_{Zsb}(v_{s2}, v_{s6}, v_{s2o})$	<i>barley storage</i>
(5.3.68)	$C_{Zsc} = Z^{sc} * c_{Zsc}(v_{s3}, v_{s7}, v_{s3o})$	<i>canola storage</i>
(5.3.69)	$C_{Zsp} = Z^{sp} * c_{Zsp}(v_{s4}, v_{s4o})$	<i>pea storage</i>
(5.3.70)	$C_{Fs} = F^s * c_{Fs}(u_{s5}, g_{so})$	<i>milling</i>
(5.3.71)	$C_{Ss} = S^s * c_{Ss}(u_{s6}, u_{s7}, u_{s10}, d_{s1}, g_{s2}, t_{so})$	<i>stockfeed manufacturing</i>
(5.3.72)	$C_{Ms} = M^s * c_{Ms}(u_{s8}, n_{so})$	<i>malt manufacturing</i>
(5.3.73)	$C_{Cs} = C^s * c_{Cs}(u_{s9}, d_{so})$	<i>oilseed crushing & refining</i>

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, following the logic presented in Equation 5.3.36, the revenue functions subject to given input levels for the six multi-output sectors in the region can be represented as:

(5.3.74)	$R_{Xs} = X^s * r_{Xs}(v_{s1}, v_{s2}, v_{s3}, v_{s4})$	<i>farm production</i>
(5.3.75)	$R_{Ysw} = Y^{sw} * r_{Ysw}(u_{s1}, u_{s5}, u_{s6},)$	<i>wheat storage</i>
(5.3.76)	$R_{Ysb} = Y^{sb} * r_{Ysb}(u_{s2}, u_{s7}, u_{s8},)$	<i>barley storage</i>
(5.3.77)	$R_{Ysc} = Y^{sc} * r_{Ysc}(u_{s3}, u_{s9})$	<i>canola storage</i>
(5.3.78)	$R_{Ysp} = Y^{sp} * r_{Ysp}(u_{s4}, u_{s10})$	<i>pea storage</i>
(5.3.79)	$R_{Zsf} = Z^{sf} * r_{Zsf}(g_{s1}, g_{s2})$	<i>milling</i>
(5.3.80)	$R_{Zss} = Z^{ss} * r_{Zs}(t_{s1}, t_{s2})$	<i>stockfeed manufacturing</i>
(5.3.81)	$R_{Zsm} = Z^{sm} * r_{Zsm}(n_{s1}, n_{s2})$	<i>malt manufacturing</i>
(5.3.82)	$R_{Zsc} = Z^{sc} * r_{Zsc}(d_{s1}, d_{s2}, d_{s3})$	<i>oilseed crushing & refining</i>

where R_x denotes the total revenue generated from the fixed input index x and r_x stands for the unit revenue function. Similarly, quantities are represented by capital letters and prices by lower case letters.

5.3.3 Northern Region

As with the western and southern regions, there are six industry sectors in the southern region EDM (farm production, up-country storage, milling, stockfeed manufacturing, malt manufacturing, and oilseed crushing and refining) whose multi-output production functions and decision making problems can be specified completely within the model.

Under the assumption that total costs equate to total revenue for each industry sector, we have:

(5.3.83)	$\sum_{i=v,o} w_{ni} X_{ni} = \sum_{i=1,2,3,4} v_{ni} Y_{ni}$	<i>farm production equilibrium</i>
(5.3.84)	$v_{n1} Y_{n1} + v_{n1o} Y_{n1o} = \sum_{i=1,5,6,11} u_{ni} Z_{ni}$	<i>wheat storage equilibrium</i>
(5.3.85)	$v_{n2} Y_{n2} + v_{n2o} Y_{n2o} = \sum_{i=2,7,8,12} u_{ni} Z_{ni}$	<i>barley storage equilibrium</i>
(5.3.86)	$v_{n3} Y_{n3} + v_{n3o} Y_{n3o} = \sum_{i=3,9,13} u_{ni} Z_{ni}$	<i>canola storage equilibrium</i>
(5.3.87)	$v_{n4} Y_{n4} + v_{n4o} Y_{n4o} = \sum_{i=4,10} u_{ni} Z_{ni}$	<i>chickpea storage equilibrium</i>
(5.3.88)	$u_{n5} Z_{n5} + g_{no} F_{no} = \sum_{i=1,2} g_{ni} F_{ni}$	<i>milling equilibrium</i>
(5.3.89)	$\sum_{i=6,7,10} u_{ni} Z_{ni} + g_{n2} F_{n2} + d_{n1} C_{n1} + t_{no} S_{no}$ $= \sum_{i=1,2} t_{ni} S_{ni}$	<i>stockfeed manufacturing equilibrium</i>
(5.3.90)	$u_{n8} Z_{n8} + n_{no} M_{no} = \sum_{i=1,2} n_{ni} M_{ni}$	<i>malt manufacturing equilibrium</i>
(5.3.91)	$u_{n9} Z_{n9} + d_{no} C_{no} = \sum_{i=1,2,3} d_{ni} C_{ni}$	<i>oilseed crushing and refining equilibrium</i>

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

(5.3.92)	$Y^n(Y_{n1}, Y_{n2}, Y_{n3}, Y_{n4}) = X^n(X_{nv}, X_{no})$	<i>farm production</i>
(5.3.93)	$Z^{nw}(Z_{n1}, Z_{n5}, Z_{n6}, Z_{n11}) = Y^{nw}(Y_{n1}, Y_{n1o})$	<i>wheat storage</i>
(5.3.94)	$Z^{nb}(Z_{n2}, Z_{n7}, Z_{n8}, Z_{n12}) = Y^{nb}(Y_{n2}, Y_{n2o})$	<i>barley storage</i>
(5.3.95)	$Z^{nc}(Z_{n3}, Z_{n9}, Z_{n13}) = Y^{nc}(Y_{n3}, Y_{n3o})$	<i>canola storage</i>
(5.3.96)	$Z^{sh}(Z_{n4}, Z_{n10}) = Y^{sh}(Y_{n4}, Y_{n4o})$	<i>pea storage</i>
(5.3.97)	$F^n(F_{n1}, F_{n2}) = Z^{nf}(Z_{n5}, F_{no})$	<i>milling</i>
(5.3.98)	$S^n(S_{n1}, S_{n2}) = Z^{ns}(Z_{n6}, Z_{n7}, Z_{n10}, C_{n1}, F_{n2}, S_{no})$	<i>stockfeed manufacturing</i>
(5.3.99)	$M^n(M_{n1}, M_{n2}) = Z^{nm}(Z_{n8}, M_{no})$	<i>malt manufacturing</i>
(5.3.100)	$C^n(C_{n1}, C_{n2}, C_{n3}) = Z^{nc}(Z_{n9}, C_{no})$	<i>oilseed crushing & refining</i>

The variables on the left sides of the equations are outputs for the relevant sectors and the variables on the right sides are the inputs.

Cost functions related to these production functions are written as:

(5.3.101)	$C_{Y^n} = Y^n * c_{Y^n}(w_{nv}, w_{no})$	<i>farm production</i>

(5.3.102)	$C_{Z^{nw}} = Z^{nw} * c_{Z^{nw}}(v_{n1}, v_{n10})$	wheat storage
(5.3.103)	$C_{Z^{nb}} = Z^{nb} * c_{Z^{nb}}(v_{n2}, v_{n20})$	barley storage
(5.3.104)	$C_{Z^{nc}} = Z^{nc} * c_{Z^{nc}}(v_{n3}, v_{n30})$	canola storage
(5.3.105)	$C_{Z^{nh}} = Z^{nh} * c_{Z^{nh}}(v_{n4}, v_{n40})$	chickpea storage
(5.3.106)	$C_{F^n} = F^n * c_{F^n}(u_{n5}, g_{n0})$	milling
(5.3.107)	$C_{S^n} = S^n * c_{S^n}(u_{n6}, u_{n7}, u_{n10}, d_{n1}, g_{n2}, t_{n0})$	stockfeed manufacturing
(5.3.108)	$C_{M^n} = M^n * c_{M^n}(u_{n8}, n_{n0})$	malt manufacturing
(5.3.109)	$C_{C^n} = C^n * c_{C^n}(u_{n9}, d_{n0})$	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 sectors can be represented as:

(5.3.110)	$R_{X^n} = X^n * r_{X^n}(v_{n1}, v_{n2}, v_{n3}, v_{n4})$	farm production
(5.3.111)	$R_{Y^{nw}} = Y^{nw} * r_{Y^{nw}}(u_{n1}, u_{n5}, u_{n6}, u_{n11})$	wheat storage
(5.3.112)	$R_{Y^{nb}} = Y^{nb} * r_{Y^{nb}}(u_{n2}, u_{n7}, u_{n8}, u_{n12})$	barley storage
(5.3.113)	$R_{Y^{nc}} = Y^{nc} * r_{Y^{nc}}(u_{n3}, u_{n9}, u_{n13})$	canola storage
(5.3.114)	$R_{Y^{nh}} = Y^{nh} * r_{Y^{nh}}(u_{n4}, u_{n10})$	chickpea storage
(5.3.115)	$R_{Z^{nf}} = Z^{nf} * r_{Z^{nf}}(g_{n1}, g_{n2})$	milling
(5.3.116)	$R_{Z^{ns}} = Z^{ns} * r_{Z^{ns}}(t_{n1}, t_{n2})$	stockfeed manufacturing
(5.3.117)	$R_{Z^{nm}} = Z^{nm} * r_{Z^{nm}}(n_{n1}, n_{n2})$	malt manufacturing
(5.3.118)	$R_{Z^{nc}} = Z^{nc} * r_{Z^{nc}}(d_{n1}, d_{n2}, d_{n3})$	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. Quantities are represented by capital letters and prices by lower case letters.

5.3.4 Profit Functions and Exogenous Supply

The following set of inputs are exogenous to the EDM system:

Western: $X_{wv}, X_{wo}, Y_{w10}, Y_{w20}, Y_{w30}, Y_{w40}, F_{wo}, S_{wo}, M_{wo}, C_{wo}$

Southern: $X_{sv}, X_{so}, Y_{s5}, Y_{s6}, Y_{s7}, Y_{s10}, Y_{s20}, Y_{s30}, Y_{s40}, F_{so}, S_{so}, M_{so}, C_{so}$

Northern: $X_{nv}, X_{no}, Y_{n1o}, Y_{n2o}, Y_{n3o}, Y_{n4o}, F_{no}, S_{no}, M_{no}, C_{no}$

The supplies of these factors are exogenous to the model. Because of this, they cannot be entirely specified within the model as the decision variables pertaining to their supplies are not entirely included in the model.

In order to derive the supply relationships of these inputs, consider the following logic (Zhao *et al.*, 2000b, p.16).

Let x represent any one of the exogenous inputs and let the production function for the producer of x be:

$$F(x, O) = 0$$

Where O is the vector of all inputs and other outputs of the production function. Following Zhao *et al.* (2000b, p.16), the profit function can be specified as:

$$(5.3.119) \pi = \max_{x,O} \{w_x x + W' O : F(x, O) = 0\} = \pi(w_x, W)$$

Where w_x is the price for x and W is the price vector for O . Following Varian (1992, p.25), each element in O is set negative if it is an input and positive if it is an output. The supply of x can be derived using Hotelling's Lemma as follows:

$$(5.3.120) x = \frac{\partial}{\partial w_x} \pi(w_x, W) = \pi'_{wx}(w_x, W) = x(w_x, W)$$

Where $\pi'_{wx}(w_x, W)$ is the partial derivative of $\pi(w_x, W)$ with respect to w_x .

The supply of each $x = X_{wv}, X_{wo}, Y_{w1o}, Y_{w2o}, Y_{w3o}, Y_{w4o}, F_{wo}, S_{wo}, M_{wo}, C_{wo}, X_{sv}, X_{so}, Y_{s5}, Y_{s6}, Y_{s7}, Y_{s1o}, Y_{s2o}, Y_{s3o}, Y_{s4o}, F_{so}, S_{so}, M_{so}, C_{so}, X_{nv}, X_{no}, Y_{n1o}, Y_{n2o}, Y_{n3o}, Y_{n4o}, F_{no}, S_{no}, M_{no}$ and C_{no} can be derived using Equation 5.3.120.

5.3.5 Utility Functions and Exogenous Demand

The demands for final grain and grain products are also exogenous to the model:

Western: $Z_{w1}, Z_{w2}, Z_{w3}, Z_{w4}, F_{w1}, S_{w1}, S_{w2}, M_{w1}, M_{w2}, C_{w2}, C_{w3}$

Southern: $Z_{s1}, Z_{s2}, Z_{s3}, Z_{s4}, F_{s1}, S_{s1}, S_{s2}, M_{s1}, M_{s2}, C_{s2}, C_{s3}$

Northern: $Z_{n1}, Z_{n2}, Z_{n3}, Z_{n4}, Z_{n11}, Z_{n12}, Z_{n13}, F_{n1}, S_{n1}, S_{n2}, M_{n1}, M_{n2}, C_{n2}, C_{n3}$

To derive the demand equations of these final outputs, we follow the logic of Zhao *et al.*, (2000b, p.16).

Suppose that the indirect utility function for a given income level m for the consumer of Z_{w1} (export wheat in the western region) can be specified as outlined by Varian (1992, p.99) and Zhao *et al.* (2000b, p.16):

$$(5.3.121) \ v(u_{w1}, P, m) = \max_{Z_{w1}, Q} \{u(Z_{w1}, Q) : u_{w1}Z_{w1} + P'Q = m\}$$

Where u_{w1} is the price of Z_{w1} , Q is the vector of all the quantities of other commodities consumed, P represents the price vector of Q and $u(\cdot)$ is the consumer's utility function. Applying Roy's identity (Jehle and Reny, 2011, p.29), the Marshallian demand equation can then be derived:

$$(5.3.122) \ Z_{w1}(u_{w1}, P, m) = - \frac{\partial v(u_{w1}, P, m) / \partial u_{w1}}{\partial v(u_{w1}, P, m) / \partial m}$$

All the exogenous demand equations can be derived using Equation 5.3.122.

5.4 The Equilibrium Displacement Model

5.4.1 Structural Form

Western Region

Here, the system of equations representing the EDM of the western region is specified. There are 84 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 six industry sectors. In addition, there are 21 exogenous variables corresponding to the products flowing into or out of the end uses (ovals) depicted in Figure 5.1. These exogenous variables are supply and demand shifters and represent the impact of new technologies and quality improvements. These equations expressed in general form are as follows:

Input supply to farm sector

$$(1) \quad X_{wv} = X_{wv}(w_{wv}, T_{xwv})$$

$$(2) \quad X_{wo} = X_{wo}(w_{wo}, T_{xwo})$$

Output-constrained input demand of farm sector

$$(3) \quad X_{wv} = Y^w * c'_{Yw,wv}(w_{wv}, w_{wo})$$

$$(4) \quad X_{wo} = Y^w * c'_{Yw,wo}(w_{wv}, w_{wo})$$

Input-constrained output supply of farm enterprises

$$(5) \quad Y_{w1} = X^w * r'_{Xw,vw1}(v_{w1}, v_{w2}, v_{w3}, v_{w4})$$

$$(6) \quad Y_{w2} = X^w * r'_{Xw,vw2}(v_{w1}, v_{w2}, v_{w3}, v_{w4})$$

$$(7) \quad Y_{w3} = X^w * r'_{Xw,vw3}(v_{w1}, v_{w2}, v_{w3}, v_{w4})$$

$$(8) \quad Y_{w4} = X^w * r'_{Xw,vw4}(v_{w1}, v_{w2}, v_{w3}, v_{w4})$$

Equilibrium conditions of farm enterprises

$$(9) \quad X^w(X_{wv}, X_{wo}) = Y^w(Y_{w1}, Y_{w2}, Y_{w3}, Y_{w4})$$

$$(10) \quad c_{Yw}(w_{wv}, w_{wo}) = r_{Xw}(v_{w1}, v_{w2}, v_{w3}, v_{w4})$$

Other input supply to wheat storage

$$(11) \quad Y_{w1o} = Y_{w1o}(v_{w1o}, T_{Yw1o})$$

Output-constrained input demand of wheat storage

$$(12) \quad Y_{w1} = Z^{ww} * c'_{Zww,vw1}(v_{w1}, v_{w1o})$$

$$(13) \quad Y_{w1o} = Z^{ww} * c'_{Zww,vw1o}(v_{w1}, v_{w1o})$$

Input-constrained output supply of wheat storage

$$(14) \quad Z_{w1} = Y^w * r'_{Yw,uw1}(u_{w1}, u_{w5}, u_{w6})$$

$$(15) \quad Z_{w5} = Y^w * r'_{Yw,uw5}(u_{w1}, u_{w5}, u_{w6})$$

$$(16) \quad Z_{w6} = Y^w * r'_{Yw,uw6}(u_{w1}, u_{w5}, u_{w6})$$

Equilibrium conditions of wheat storage

$$(17) \quad Y^{ww}(Y_{w1}, Y_{w1o}) = Z^{ww}(Z_{w1}, Z_{w5}, Z_{w6})$$

$$(18) \quad c_{Zww}(v_{w1}, v_{w1o}) = r_{Yww}(u_{w1}, u_{w5}, u_{w6})$$

Export Demand for wheat

$$(19) \quad Z_{w1} = Z_{w1}(u_{w1}, N_{Zw1})$$

Other input supply to barley storage

$$(20) \quad Y_{w2o} = Y_{w2o}(v_{w2o}, T_{Yw2o})$$

Output-constrained input demand of barley storage

$$(21) \quad Y_{w2} = Z^{wb} * c'_{Zwb,vw2}(v_{w2}, v_{w2o})$$

$$(22) \quad Y_{w2o} = Z^{wb} * c'_{Zwb,vw2o}(v_{w2}, v_{w2o})$$

Input-constrained output supply of barley storage

$$(23) \quad Z_{w2} = Y^{wb} * r'_{Ywb,uw2}(u_{w2}, u_{w7}, u_{w8})$$

$$(24) \quad Z_{w7} = Y^{wb} * r'_{Ywb,uw7}(u_{w2}, u_{w7}, u_{w8})$$

$$(25) \quad Z_{w8} = Y^{wb} * r'_{Ywb,uw8}(u_{w2}, u_{w7}, u_{w8})$$

Equilibrium conditions of barley storage

$$(26) \quad Y^{wb}(Y_{w2}, Y_{w2o}) = Z^{wb}(Z_{w2}, Z_{w7}, Z_{w8})$$

$$(27) \quad c_{Zwb}(v_{w2}, v_{w2o}) = r_{Ywb}(u_{w2}, u_{w7}, u_{w8})$$

Export Demand for barley

$$(28) \quad Z_{w2} = Z_{w2}(u_{w2}, N_{Zw2})$$

Other input supply to canola storage

$$(29) \quad Y_{w3o} = Y_{w3o}(v_{w3o}, T_{Yw3o})$$

Output-constrained input demand of canola storage

$$(30) \quad Y_{w3} = Z^{wc} * c'_{Zwc,vw3}(v_{w3}, v_{w3o})$$

$$(31) \quad Y_{w3o} = Z^{wc} * c'_{Zwc,vw3o}(v_{w2}, v_{w3o})$$

Input-constrained output supply of canola storage

$$(32) \quad Z_{w3} = Y^{wc} * r'_{Ywc,uw3}(u_{w3}, u_{w9})$$

$$(33) \quad Z_{w9} = Y^{wc} * r'_{Ywc,uw9}(u_{w3}, u_{w9})$$

Equilibrium conditions of canola storage

$$(34) \quad Y^{wc}(Y_{w3}, Y_{w3o}) = Z^{wc}(Z_{w3}, Z_{w9})$$

$$(35) \quad c_{Zwc}(v_{w3}, v_{w3o}) = r_{Ywc}(u_{w3}, u_{w9})$$

Export Demand for canola

$$(36) \quad Z_{w3} = Z_{w3}(u_{w3}, N_{Zw3})$$

Other input supply to lupin storage

$$(37) \quad Y_{w4o} = Y_{w4o}(v_{w4o}, T_{Yw4o})$$

Output-constrained input demand of lupin storage

$$(38) \quad Y_{w4} = Z^{wl} * c'_{Zwl,vw4}(v_{w4}, v_{w4o})$$

$$(39) \quad Y_{w4o} = Z^{wl} * c'_{Zwl,v4o}(v_{w4}, v_{w4o})$$

Input-constrained output supply of lupin storage

$$(40) \quad Z_{w4} = Y^{wl} * r'_{Ywl,uw4}(u_{w4}, u_{w10})$$

$$(41) \quad Z_{w10} = Y^{wl} * r'_{Ywl,uw10}(u_{w4}, u_{w10})$$

Equilibrium conditions of lupin storage

$$(42) \quad Y^{wl}(Y_{w4}, Y_{w4o}) = Z^{wl}(Z_{w4}, Z_{w10})$$

$$(43) \quad c_{Zwl}(v_{w1}, v_{w1o}) = r_{Ywl}(u_{w4}, u_{w10})$$

Export demand of lupins

$$(44) \quad Z_{w4} = Z_{w4}(u_{w4}, N_{Zw4})$$

Other input supply to milling sector

$$(45) \quad F_{w0} = F_{w0}(g_{w0}, T_{Fw0})$$

Output-constrained input demand of milling sector

$$(46) \quad Z_{w5} = F^w * c'_{Fw,uw5}(u_{w5}, g_{w0})$$

$$(47) \quad F_{w0} = F^w * c'_{Fw,gw0}(u_{w5}, g_{w0})$$

Input-constrained output supply of milling sector

$$(48) \quad F_{w1} = Z^{wf} * r'_{Zwf,gw1}(g_{w1}, g_{w2})$$

$$(49) \quad F_{w2} = Z^{wf} * r'_{Zwf,gw2}(g_{w1}, g_{w2})$$

Equilibrium conditions of milling sector

$$(50) \quad F^w(F_{w1}, F_{w2}) = Z^{wf}(Z_{w5}, F_{w0})$$

$$(51) \quad c_{Zwf}(u_{w5}, g_{w0}) = r_{Fw}(g_{w1}, g_{w2})$$

Domestic demand of milling sector

$$(52) \quad F_{w1} = F_{w1}(g_{w1}, N_{Fw1})$$

Other input supply to stockfeed sector

$$(53) \quad S_{w0} = S_{w0}(t_{w0}, T_{Sw0})$$

Output-constrained input demand of stockfeed sector

$$(54) \quad Z_{w6} = S^w * c'_{Sw,Zw6}(u_{w6}, u_{w7}, u_{w10}, g_{w2}, d_{w1}, t_{w0})$$

$$(55) \quad Z_{w7} = S^w * c'_{Sw,Zw7}(u_{w6}, u_{w7}, u_{w10}, g_{w2}, d_{w1}, t_{w0})$$

$$(56) \quad Z_{w10} = S^w * c'_{Sw,Zw10}(u_{w6}, u_{w7}, u_{w10}, g_{w2}, d_{w1}, t_{w0})$$

$$(57) \quad F_{w2} = S^w * c'_{Sw,gw2}(u_{w6}, u_{w7}, u_{w10}, g_{w2}, d_{w1}, t_{w0})$$

$$(58) \quad C_{w1} = S^w * c'_{Sw,dw1}(u_{w6}, u_{w7}, u_{w10}, g_{w2}, d_{w1}, t_{w0})$$

$$(59) \quad S_{w0} = S^w * c'_{Sw,tw0}(u_{w6}, u_{w7}, u_{w10}, g_{w2}, d_{w1}, t_{w0})$$

Input-constrained output supply of stockfeed sector

$$(60) \quad S_{w1} = Z^{ws} * r'_{Zws,tw1}(t_{w1}, t_{w2})$$

$$(61) \quad S_{w2} = Z^{ws} * r'_{Zws,tw2}(t_{w1}, t_{w2})$$

Equilibrium conditions of stockfeed sector

$$(62) \quad Z_{ws}(Z_{w6}, Z_{w7}, Z_{w10}, C_{w1}, F_{w2}, S_{w0}) = S^w(S_{w1}, S_{w2})$$

$$(63) \quad c_{Sw}(u_{w6}, u_{w7}, u_{w10}, d_{w1}, g_{w2}, t_{w0}) = r_{Zws}(t_{w1}, t_{w2})$$

Export demand of stockfeed sector

$$(64) \quad S_{w1} = S_{w1}(t_{w1}, N_{Sw1})$$

Domestic demand of stockfeed sector

$$(65) \quad S_{w2} = S_{w2}(t_{w2}, N_{Sw2})$$

Other input supply to malt manufacturing sector

$$(66) \quad M_{w0} = M_{w0}(n_{w0}, T_{Mw0})$$

Output-constrained input demand of malt manufacturing sector

$$(67) \quad Z_{w8} = M^w * c'_{Mw,gw2}(u_{w8}, n_{w0})$$

$$(68) \quad M_{w0} = M^w * c'_{Mw,nw0}(u_{w8}, n_{w0})$$

Input-constrained output supply of malt manufacturing sector

$$(69) \quad M_{w1} = Z^{wm} * r'_{Zwm,nw1}(n_{w1}, n_{w2})$$

$$(70) \quad M_{w2} = Z^{wm} * r'_{Zwm,nw2}(n_{w1}, n_{w2})$$

Equilibrium conditions of malt manufacturing sector

$$(71) \quad Z^{wm}(Z_{w8}, M_{w0}) = M^w(M_{w1}, M_{w2})$$

$$(72) \quad c_{Mw}(u_{w8}, n_{w0}) = r_{Zwm}(n_{w1}, n_{w2})$$

Export demand of malt manufacturing sector

$$(73) \quad M_{w1} = M_{w1}(n_{w1}, N_{Mw1})$$

Domestic demand of malt manufacturing sector

$$(74) \quad M_{w2} = M_{w2}(n_{w2}, N_{Mw2})$$

Other input supply to oilseed crushing and refining sector

$$(75) \quad C_{w0} = C_{w0}(d_{w0}, T_{Cw0})$$

Output-constrained input demand of oilseed crushing and refining sector

$$(76) \quad Z_{w9} = C^w * c'_{Cw,uw9}(u_{w9}, d_{w0})$$

$$(77) \quad C_{w0} = C^w * c'_{Cw,dw0}(u_{w9}, d_{w0})$$

Input-constrained output supply of oilseed crushing and refining sector

$$(78) \quad C_1 = Z^c * r'_{Zwc,dw1}(d_{w1}, d_{w2}, d_{w3})$$

$$(79) \quad C_2 = Z^c * r'_{Zwc,dw2}(d_{w1}, d_{w2}, d_{w3})$$

$$(80) \quad C_3 = Z^c * r'_{Zwc,dw3}(d_{w1}, d_{w2}, d_{w3})$$

Equilibrium conditions of oilseed crushing and refining sector

$$(81) \quad Z^{wc}(Z_{w9}, C_{w0}) = C^w(C_{w1}, C_{w2}, C_{w3})$$

$$(82) \quad c_{cw}(u_{w9}, d_{w0}) = r_{Zwc}(d_{w1}, d_{w2}, d_{w3})$$

Export demand of oilseed crushing and refining sector

$$(83) \quad C_{w2} = C_{w2}(d_{w2}, N_{cw2})$$

Domestic demand of oilseed crushing and refining sector

$$(84) \quad C_{w3} = C_{w3}(d_{w3}, N_{cw3})$$

Southern Region

Next, the system of equations representing the EDM of the southern region is 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 sectors. In addition, there are 24 exogenous variables corresponding to the products flowing into or out of the end uses (ovals) depicted in Figure 5.2. These exogenous variables are supply and demand shifters and represent the impact of new technologies and quality improvements. These equations expressed in general form are as follows:

Input supply to farm sector

$$(85) \quad X_{sv} = X_{sv}(w_{sv}, T_{Xsv})$$

$$(86) \quad X_{so} = X_{so}(w_{so}, T_{Xso})$$

Output-constrained input demand of farm sector

$$(87) \quad X_{sv} = Y^s * c'_{Ys,sv}(w_{sv}, w_{so})$$

$$(88) \quad X_{so} = Y^s * c'_{Ys,so}(w_{sv}, w_{so})$$

Input-constrained output supply of farm enterprises

$$(89) \quad Y_{s1} = X^s * r'_{Xs,vs1}(v_{s1}, v_{s2}, v_{s3}, v_{s4})$$

$$(90) \quad Y_{s2} = X^s * r'_{Xs,vs2}(v_{s1}, v_{s2}, v_{s3}, v_{s4})$$

$$(91) \quad Y_{s3} = X^s * r'_{Xs,vs3}(v_{s1}, v_{s2}, v_{s3}, v_{s4})$$

$$(92) \quad Y_{s4} = X^s * r'_{Xs,vs4}(v_{s1}, v_{s2}, v_{s3}, v_{s4})$$

Equilibrium conditions of farm enterprises

$$(93) \quad X^s(X_{sv}, X_{so}) = Y^s(Y_{s1}, Y_{s2}, Y_{s3}, Y_{s4})$$

$$(94) \quad c_{Ys}(w_{sv}, w_{so}) = r_{Xs}(v_{s1}, v_{s2}, v_{s3}, v_{s4})$$

Other input supply to wheat storage

$$(95) \quad Y_{s10} = Y_{s10}(v_{s10}, T_{Ys10})$$

Grain supply from other region to wheat storage sector

$$(96) \quad Y_{s5} = Y_{s5}(v_{s5}, T_{Ys5})$$

Output-constrained input demand of wheat storage

$$(97) \quad Y_{s1} = Z^{sw} * c'_{Zsw,vs1}(v_{s1}, v_{s5}, v_{s10})$$

$$(98) \quad Y_{s5} = Z^{sw} * c'_{Zsw,vs5}(v_{s1}, v_{s5}, v_{s10})$$

$$(99) \quad Y_{s10} = Z^{sw} * c'_{Zsw,vs10}(v_{s1}, v_{s5}, v_{s10})$$

Input-constrained output supply of wheat storage

$$(100) \quad Z_{s1} = Y^{sw} * r'_{Ysw,us1}(u_{s1}, u_{s5}, u_{s6})$$

$$(101) \quad Z_{s5} = Y^{sw} * r'_{Ysw,us5}(u_{s1}, u_{s5}, u_{s6})$$

$$(102) \quad Z_{s6} = Y^{sw} * r'_{Ysw,us6}(u_{s1}, u_{s5}, u_{s6})$$

Equilibrium conditions of wheat storage

$$(103) \quad Y^{sw}(Y_{s1}, Y_{s5}, Y_{s10}) = Z^{sw}(Z_{s1}, Z_{s5}, Z_{s6})$$

$$(104) \quad c_{Zsw}(v_{s1}, v_{s5}, v_{s10}) = r_{Ysw}(u_{s1}, u_{s5}, u_{s6})$$

Export Demand for wheat

$$(105) \quad Z_{s1} = Z_{s1}(u_{s1}, N_{Zs1})$$

Other input supply to barley storage

$$(106) \quad Y_{s20} = Y_{s20}(v_{s20}, T_{Ys20})$$

Grain supply from other region to barley storage sector

$$(107) \quad Y_{s6} = Y_{s6}(v_{s6}, T_{Ys6})$$

Output-constrained input demand of barley storage

$$(108) \quad Y_{s2} = Z^{sb} * c'_{Zsb,vs2}(v_{s2}, v_{s6}, v_{s2o})$$

$$(109) \quad Y_{s6} = Z^{sb} * c'_{Zsb,vs6}(v_{s2}, v_{s6}, v_{s2o})$$

$$(110) \quad Y_{s2o} = Z^{sb} * c'_{Zsb,vs2o}(v_{s2}, v_{s6}, v_{s2o})$$

Input-constrained output supply of barley storage

$$(111) \quad Z_{s2} = Y^{sb} * r'_{Ysb,us2}(u_{s2}, u_{w7}, u_{w8})$$

$$(112) \quad Z_{s7} = Y^{sb} * r'_{Ysb,us7}(u_{s2}, u_{s7}, u_{s8})$$

$$(113) \quad Z_{s8} = Y^{sb} * r'_{Ysb,us8}(u_{s2}, u_{s7}, u_{s8})$$

Equilibrium conditions of barley storage

$$(114) \quad Y^{sb}(Y_{s2}, Y_{s6}, Y_{s2o}) = Z^{sb}(Z_{s2}, Z_{s7}, Z_{s8})$$

$$(115) \quad c_{Zsb}(v_{s2}, v_{s6}, v_{s2o}) = r_{Ysb}(u_{s2}, u_{s7}, u_{s8})$$

Export Demand for barley

$$(116) \quad Z_{s2} = Z_{s2}(u_{s2}, N_{Zs2})$$

Other input supply to canola storage

$$(117) \quad Y_{s3o} = Y_{s3o}(v_{s3o}, T_{Ys3o})$$

Grain supply from other regions to canola storage sector

$$(118) \quad Y_{s7} = Y_{s7}(v_{s7}, T_{Ys7})$$

Output-constrained input demand of canola storage

$$(119) \quad Y_{s3} = Z^{sc} * c'_{Zsc,vs3}(v_{s3}, v_{s7}, v_{s3o})$$

$$(120) \quad Y_{s7} = Z^{sc} * c'_{Zsc,vs3o}(v_{s2}, v_{s7}, v_{s2o})$$

$$(121) \quad Y_{s3o} = Z^{sc} * c'_{Zsc,vs3o}(v_{s2}, v_{s7}, v_{s3o})$$

Input-constrained output supply of canola storage

$$(122) \quad Z_{s3} = Y^{sc} * r'_{Ysc,us3}(u_{s3}, u_{s9})$$

$$(123) \quad Z_{s9} = Y^{sc} * r'_{Ysc,us9}(u_{s3}, u_{s9})$$

Equilibrium conditions of canola storage

$$(124) \quad Y^{sc}(Y_{s3}, Y_{s7}, Y_{s30}) = Z^{sc}(Z_{s3}, Z_{s9})$$

$$(125) \quad c_{Zsc}(v_{s3}, v_{s7}, v_{s30}) = r_{Ysc}(u_{s3}, u_{s9})$$

Export Demand for canola

$$(126) \quad Z_{s3} = Z_{s3}(u_{s3}, N_{Zs3})$$

Other input supply to pea storage

$$(127) \quad Y_{s40} = Y_{s40}(v_{s40}, T_{Ys40})$$

Output-constrained input demand of pea storage

$$(128) \quad Y_{s4} = Z^{sl} * c'_{Zsl,vs4}(v_{s4}, v_{s40})$$

$$(129) \quad Y_{s40} = Z^{sl} * c'_{Zsl,vs40}(v_{s4}, v_{s40})$$

Input-constrained output supply of pea storage

$$(130) \quad Z_{s4} = Y^{sl} * r'_{Ysl,us4}(u_{s4}, u_{s10})$$

$$(131) \quad Z_{s10} = Y^{sl} * r'_{Ysl,us10}(u_{s4}, u_{s10})$$

Equilibrium conditions of pea storage

$$(132) \quad Y^{sl}(Y_{s4}, Y_{s40}) = Z^{sl}(Z_{s4}, Z_{s10})$$

$$(133) \quad c_{Zsl}(v_{s1}, v_{s10}) = r_{Ysl}(u_{s4}, u_{s10})$$

Export demand of peas

$$(134) \quad Z_{s4} = Z_{s4}(u_{s4}, N_{Zs4})$$

Other input supply to milling sector

$$(135) \quad F_{s0} = F_{s0}(g_{s0}, T_{Fs0})$$

Output-constrained input demand of milling sector

$$(136) \quad Z_{s5} = F^s * c'_{Fs,us5}(u_{s5}, g_{s0})$$

$$(137) \quad F_{s0} = F^s * c'_{Fs,gs0}(u_{s5}, g_{s0})$$

Input-constrained output supply of milling sector

$$(138) \quad F_{s1} = Z^{sf} * r'_{Zsf,gs1}(g_{s1}, g_{s2})$$

$$(139) \quad F_{s2} = Z^{sf} * r'_{Zsf,gs2}(g_{s1}, g_{s2})$$

Equilibrium conditions of milling sector

$$(140) \quad F^s(F_{s1}, F_{s2},) = Z^{sf}(Z_{s5}, F_{s0})$$

$$(141) \quad c_{Fs}(u_{s5}, g_{s0}) = r_{Zsf}(g_{s1}, g_{s2})$$

Domestic demand of milling sector

$$(142) \quad F_{s1} = F_{s1}(g_{s1}, N_{Fs1})$$

Other input supply to stockfeed sector

$$(143) \quad S_{s0} = S_{s0}(t_{s0}, T_{sso})$$

Output-constrained input demand of stockfeed sector

$$(144) \quad Z_{s6} = S^s * c'_{Ss,Zs6}(u_{s6}, u_{s7}, u_{s10}, g_{s2}, d_{s1}, t_{s0})$$

$$(145) \quad Z_{s7} = S^s * c'_{Ss,Zs7}(u_{s6}, u_{s7}, u_{s10}, g_{s2}, d_{s1}, t_{s0})$$

$$(146) \quad Z_{s10} = S^s * c'_{Ss,Zs10}(u_{s6}, u_{s7}, u_{s10}, g_{s2}, d_{s1}, t_{s0})$$

$$(147) \quad F_{s2} = S^s * c'_{Ss,gs2}(u_{s6}, u_{s7}, u_{s10}, g_{s2}, d_{s1}, t_{s0})$$

$$(148) \quad C_{s1} = S^s * c'_{Ss,ds1}(u_{s6}, u_{s7}, u_{s10}, g_{s2}, d_{s1}, t_{s0})$$

$$(149) \quad S_{s0} = S^s * c'_{Ss,tso}(u_{s6}, u_{s7}, u_{s10}, g_{s2}, d_{s1}, t_{s0})$$

Input-constrained output supply of stockfeed sector

$$(150) \quad S_{s1} = Z^{ss} * r'_{Zss,ts1}(t_{s1}, t_{s2})$$

$$(151) \quad S_{s2} = Z^{ss} * r'_{Zss,ts2}(t_{s1}, t_{s2})$$

Equilibrium conditions of stockfeed sector

$$(152) \quad Z_{ss}(Z_{s6}, Z_{s7}, Z_{s10}, C_{s1}, F_{s2}, S_{s0}) = S^s(S_{s1}, S_{s2})$$

$$(153) \quad c_{Ss}(u_{s6}, u_{s7}, u_{s10}, d_{s1}, g_{s2}, t_{s0}) = r_{Zss}(t_{s1}, t_{s2})$$

Export demand of stockfeed sector

$$(154) \quad S_{s1} = S_{s1}(t_{s1}, N_{ss1})$$

Domestic demand of stockfeed sector

$$(155) \quad S_{s2} = S_{s2}(t_{s2}, N_{s2})$$

Other input supply to malt manufacturing sector

$$(156) \quad M_{so} = M_{so}(n_{so}, T_{Mso})$$

Output-constrained input demand of malt manufacturing sector

$$(157) \quad Z_{s8} = M^s * c'_{Ms,gs2}(u_{s8}, n_{so})$$

$$(158) \quad M_{so} = M^s * c'_{Ms,nso}(u_{s8}, n_{so})$$

Input-constrained output supply of malt manufacturing sector

$$(159) \quad M_{s1} = Z^{sm} * r'_{Zsm,nS1}(n_{s1}, n_{s2})$$

$$(160) \quad M_{s2} = Z^{sm} * r'_{Zsm,nS2}(n_{s1}, n_{s2})$$

Equilibrium conditions of malt manufacturing sector

$$(161) \quad Z^{sm}(Z_{s8}, M_{so}) = M^s(M_{s1}, M_{s2})$$

$$(162) \quad c_{Ms}(u_{s8}, n_{so}) = r_{Zsm}(n_{s1}, n_{s2})$$

Export demand of malt manufacturing sector

$$(163) \quad M_{s1} = M_{s1}(n_{s1}, N_{Ms1})$$

Domestic demand of malt manufacturing sector

$$(164) \quad M_{s2} = M_{s2}(n_{s2}, N_{Ms2})$$

Other input supply to oilseed crushing and refining sector

$$(165) \quad C_{so} = C_{so}(d_{so}, T_{Cso})$$

Output-constrained input demand of oilseed crushing and refining sector

$$(166) \quad Z_{s9} = C^s * c'_{Cs,us9}(u_{s9}, d_{so})$$

$$(167) \quad C_{so} = C^s * c'_{Cs,dso}(u_{s9}, d_{so})$$

Input-constrained output supply of oilseed crushing and refining sector

$$(168) \quad C_1 = Z^c * r'_{Zsc,dS1}(d_{s1}, d_{s2}, d_{s3})$$

$$(169) \quad C_2 = Z^c * r'_{Zsc,dS2}(d_{s1}, d_{s2}, d_{s3})$$

$$(170) \quad C_2 = Z^c * r'_{Zsc,dS3}(d_{s1}, d_{s2}, d_{s3})$$

Equilibrium conditions of oilseed crushing and refining sector

$$(171) \quad Z^{sc}(Z_{s9}, C_{so}) = C^s(C_{s1}, C_{s2}, C_{s3})$$

$$(172) \quad c_{Cs}(u_{s9}, d_{so}) = r_{Zsc}(d_{s1}, d_{s2}, d_{s3})$$

Export demand of oilseed crushing and refining sector

$$(173) \quad C_{s2} = C_{s2}(d_{s2}, N_{Cs2})$$

Domestic demand of oilseed crushing and refining sector

$$(174) \quad C_{s3} = C_{s3}(d_{s3}, N_{Cs3})$$

Northern Region

Next, the system of equations representing the EDM of the southern region is 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 sectors. In addition, there are 24 exogenous variables corresponding to the products flowing into or out of the end uses (ovals) depicted in Figure 5.3. These exogenous variables are supply and demand shifters and represent the impact of new technologies and quality improvements. These equations expressed in general form are as follows:

Input supply to farm sector

$$(175) \quad X_{nv} = X_{nv}(w_{nv}, T_{Xsv})$$

$$(176) \quad X_{no} = X_{no}(w_{no}, T_{Xso})$$

Output-constrained input demand of farm sector

$$(177) \quad X_{nv} = Y^n * c'_{Yn,nv}(w_{nv}, w_{no})$$

$$(178) \quad X_{no} = Y^n * c'_{Yn,no}(w_{nv}, w_{no})$$

Input-constrained output supply of farm enterprises

$$(179) \quad Y_{n1} = X^n * r'_{Xn,vn1}(v_{n1}, v_{n2}, v_{n3}, v_{n4})$$

$$(180) \quad Y_{n2} = X^n * r'_{Xn,vn2}(v_{n1}, v_{n2}, v_{n3}, v_{n4})$$

$$(181) \quad Y_{n3} = X^n * r'_{Xn,vn3}(v_{n1}, v_{n2}, v_{n3}, v_{n4})$$

$$(182) \quad Y_{n4} = X^n * r'_{Xn,vn4}(v_{n1}, v_{n2}, v_{n3}, v_{n4})$$

Equilibrium conditions of farm enterprises

$$(183) \quad X^n(X_{nv}, X_{no}) = Y^n(Y_{n1}, Y_{n2}, Y_{n3}, Y_{n4})$$

$$(184) \quad c_{Yn}(w_{nv}, w_{no}) = r_{Xn}(v_{n1}, v_{n2}, v_{n3}, v_{n4})$$

Other input supply to wheat storage

$$(185) \quad Y_{n1o} = Y_{n1o}(v_{n1o}, T_{Yn1o})$$

Output-constrained input demand of wheat storage

$$(186) \quad Y_{n1} = Z^{nw} * c'_{Znw, vn1}(v_{n1}, v_{n1o})$$

$$(187) \quad Y_{n1o} = Z^{nw} * c'_{Znw, vn1o}(v_{n1}, v_{n1o})$$

Input-constrained output supply of wheat storage

$$(188) \quad Z_{n1} = Y^{nw} * r'_{Ynw, un1}(u_{n1}, u_{n5}, u_{n6}, u_{n11})$$

$$(189) \quad Z_{n5} = Y^{nw} * r'_{Ynw, un5}(u_{n1}, u_{n5}, u_{n6}, u_{n11})$$

$$(190) \quad Z_{n6} = Y^{nw} * r'_{Ynw, un6}(u_{n1}, u_{n5}, u_{n6}, u_{n11})$$

$$(191) \quad Z_{n11} = Y^{nw} * r'_{Ynw, un11}(u_{n1}, u_{n5}, u_{n6}, u_{n11})$$

Equilibrium conditions of wheat storage

$$(192) \quad Y^{nw}(Y_{n1}, Y_{n1o}) = Z^{nw}(Z_{n1}, Z_{n6}, Z_{n11})$$

$$(193) \quad c_{Znw}(v_{n1}, v_{n1o}) = r_{Ynw}(u_{n1}, u_{n6}, u_{n11})$$

Export Demand for wheat

$$(194) \quad Z_{n1} = Z_{n1}(u_{n1}, N_{Zn1})$$

Inter-regional demand for wheat

$$(195) \quad Z_{n11} = Z_{n11}(u_{n11}, N_{Zn11})$$

Other input supply to barley storage

$$(196) \quad Y_{n2o} = Y_{n2o}(v_{n2o}, T_{Yn2o})$$

Output-constrained input demand of barley storage

$$(197) \quad Y_{n2} = Z^{nb} * c'_{Znb, vn2}(v_{n2}, v_{n2o})$$

$$(198) \quad Y_{n2o} = Z^{nb} * c'_{Znb, vn2o}(v_{n2}, v_{n2o})$$

Input-constrained output supply of barley storage

$$(199) \quad Z_{n2} = Y^{nb} * r'_{Ynb,un2}(u_{n2}, u_{n7}, u_{n8}, u_{n12})$$

$$(200) \quad Z_{n7} = Y^{nb} * r'_{Ynb,un7}(u_{n2}, u_{n7}, u_{n8}, u_{n12})$$

$$(201) \quad Z_{n8} = Y^{nb} * r'_{Ynb,un8}(u_{n2}, u_{n7}, u_{n8}, u_{n12})$$

$$(202) \quad Z_{n12} = Y^{nb} * r'_{Ynb,un12}(u_{n2}, u_{n7}, u_{n8}, u_{n12})$$

Equilibrium conditions of barley storage

$$(203) \quad Y^{nb}(Y_{n2}, Y_{n2o}) = Z^{nb}(Z_{n2}, Z_{n7}, Z_{n8}, Z_{n12})$$

$$(204) \quad c_{Znb}(v_{n2}, v_{n2o}) = r_{Ynb}(u_{n2}, u_{n7}, u_{n8}, u_{n12})$$

Export Demand for barley

$$(205) \quad Z_{n2} = Z_{n2}(u_{n2}, N_{Zn2})$$

Inter-regional demand for barley

$$(206) \quad Z_{n12} = Z_{n12}(u_{n12}, N_{Zn12})$$

Other input supply to canola storage

$$(207) \quad Y_{n3o} = Y_{n3o}(v_{n3o}, T_{Yn3o})$$

Output-constrained input demand of canola storage

$$(208) \quad Y_{n3} = Z^{nc} * c'_{Znc,vn3}(v_{n3}, v_{n3o})$$

$$(209) \quad Y_{n3o} = Z^{nc} * c'_{Znc,vn3o}(v_{n3}, v_{n3o})$$

Input-constrained output supply of canola storage

$$(210) \quad Z_{n3} = Y^{nc} * r'_{Ync,un3}(u_{n3}, u_{n9}, u_{n13})$$

$$(211) \quad Z_{n9} = Y^{nc} * r'_{Ync,un9}(u_{n3}, u_{n9}, u_{n13})$$

$$(212) \quad Z_{n13} = Y^{nc} * r'_{Ync,un13}(u_{n3}, u_{n9}, u_{n13})$$

Equilibrium conditions of canola storage

$$(213) \quad Y^{nc}(Y_{n3}, Y_{n3o}) = Z^{nc}(Z_{n3}, Z_{n9}, Z_{n13})$$

$$(214) \quad c_{Znc}(v_{n3}, v_{n3o}) = r_{Ync}(u_{n3}, u_{n9}, u_{n13})$$

Export Demand for canola

$$(215) \quad Z_{n3} = Z_{n3}(u_{n3}, N_{Zn3})$$

Inter-regional demand for barley

$$(216) \quad Z_{n13} = Z_{n13}(u_{n13}, N_{Zn13})$$

Other input supply to chickpea storage

$$(217) \quad Y_{n40} = Y_{n40}(v_{n40}, T_{Yn40})$$

Output-constrained input demand of chickpea storage

$$(218) \quad Y_{n4} = Z^{nl} * c'_{Znl,vn4}(v_{n4}, v_{n40})$$

$$(219) \quad Y_{n40} = Z^{nl} * c'_{Znl,vn40}(v_{n4}, v_{n40})$$

Input-constrained output supply of chickpea storage

$$(220) \quad Z_{n4} = Y^{nl} * r'_{Ynl,un4}(u_{n4}, u_{n10})$$

$$(221) \quad Z_{n10} = Y^{nl} * r'_{Ynl,un10}(u_{n4}, u_{n10})$$

Equilibrium conditions of chickpea storage

$$(222) \quad Y^{nl}(Y_{n4}, Y_{n40}) = Z^{nl}(Z_{n4}, Z_{n10})$$

$$(223) \quad c_{Znl}(v_{n1}, v_{n10}) = r_{Ynl}(u_{n4}, u_{n10})$$

Export demand of chickpeas

$$(224) \quad Z_{n4} = Z_{n4}(u_{n4}, N_{Zn4})$$

Other input supply to milling sector

$$(225) \quad F_{no} = F_{no}(g_{no}, T_{Fno})$$

Output-constrained input demand of milling sector

$$(226) \quad Z_{n5} = F^n * c'_{Fn,un5}(u_{n5}, g_{no})$$

$$(227) \quad F_{no} = F^n * c'_{Fn,gno}(u_{n5}, g_{no})$$

Input-constrained output supply of milling sector

$$(228) \quad F_{n1} = Z^{nf} * r'_{Znf,g_{n1}}(g_{n1}, g_{n2})$$

$$(229) \quad F_{n2} = Z^{nf} * r'_{Znf,g_{n2}}(g_{n1}, g_{n2})$$

Equilibrium conditions of milling sector

$$(230) \quad F^n(F_{n1}, F_{n2},) = Z^{nf}(Z_{n5}, F_{no})$$

$$(231) \quad c_{Fn}(u_{n5}, g_{no}) = r_{Znf}(g_{n1}, g_{n2})$$

Domestic demand of milling sector

$$(232) \quad F_{n1} = F_{n1}(g_{n1}, N_{Fn1})$$

Other input supply to stockfeed sector

$$(233) \quad S_{no} = S_{no}(t_{no}, T_{Sno})$$

Output-constrained input demand of stockfeed sector

$$(234) \quad Z_{n6} = S^n * c'_{Sn,Zn6}(u_{n6}, u_{n7}, u_{n10}, g_{n2}, d_{n1}, t_{no})$$

$$(235) \quad Z_{n7} = S^n * c'_{Sn,Zn7}(u_{n6}, u_{n7}, u_{n10}, g_{n2}, d_{n1}, t_{no})$$

$$(236) \quad Z_{n10} = S^n * c'_{Sn,Zn10}(u_{n6}, u_{n7}, u_{n10}, g_{n2}, d_{n1}, t_{no})$$

$$(237) \quad F_{n2} = S^n * c'_{Sn,g_{n2}}(u_{n6}, u_{n7}, u_{n10}, g_{n2}, d_{n1}, t_{no})$$

$$(238) \quad C_{n1} = S^n * c'_{Sn,d_{n1}}(u_{n6}, u_{n7}, u_{n10}, g_{n2}, d_{n1}, t_{no})$$

$$(239) \quad S_{no} = S^n * c'_{Sn,t_{no}}(u_{n6}, u_{n7}, u_{n10}, g_{n2}, d_{n1}, t_{no})$$

Input-constrained output supply of stockfeed sector

$$(240) \quad S_{n1} = Z^{ns} * r'_{Zns,t_{n1}}(t_{n1}, t_{n2})$$

$$(241) \quad S_{n2} = Z^{ns} * r'_{Zns,t_{n2}}(t_{n1}, t_{n2})$$

Equilibrium conditions of stockfeed sector

$$(242) \quad Z_{ns}(Z_{n6}, Z_{n7}, Z_{n10}, C_{n1}, F_{n2}, S_{no}) = S^n(S_{n1}, S_{n2})$$

$$(243) \quad c_{Sn}(u_{n6}, u_{n7}, u_{n10}, d_{n1}, g_{n2}, t_{no}) = r_{Zns}(t_{n1}, t_{n2})$$

Export demand of stockfeed sector

$$(244) \quad S_{n1} = S_{n1}(t_{n1}, N_{Sn1})$$

Domestic demand of stockfeed sector

$$(245) \quad S_{n2} = S_{n2}(t_{n2}, N_{Sn2})$$

Other input supply to malt manufacturing sector

$$(246) \quad M_{no} = M_{no}(n_{no}, T_{Mno})$$

Output-constrained input demand of malt manufacturing sector

$$(247) \quad Z_{n8} = M^n * c'_{Mn,gn2}(u_{n8}, n_{no})$$

$$(248) \quad M_{no} = M^n * c'_{Mn,nn0}(u_{n8}, n_{no})$$

Input-constrained output supply of malt manufacturing sector

$$(249) \quad M_{n1} = Z^{nm} * r'_{Znm,nn1}(n_{n1}, n_{n2})$$

$$(250) \quad M_{n2} = Z^{nm} * r'_{Znm,nn2}(n_{n1}, n_{n2})$$

Equilibrium conditions of malt manufacturing sector

$$(251) \quad Z^{nm}(Z_{n8}, M_{no}) = M^n(M_{n1}, M_{n2})$$

$$(252) \quad c_{Mn}(u_{n8}, n_{no}) = r_{Znm}(n_{n1}, n_{n2})$$

Export demand of malt manufacturing sector

$$(253) \quad M_{n1} = M_{n1}(n_{n1}, N_{Mn1})$$

Domestic demand of malt manufacturing sector

$$(254) \quad M_{n2} = M_{n2}(n_{n2}, N_{Mn2})$$

Other input supply to oilseed crushing and refining sector

$$(255) \quad C_{no} = C_{no}(d_{no}, T_{Cno})$$

Output-constrained input demand of oilseed crushing and refining sector

$$(256) \quad Z_{n9} = C^n * c'_{Cn,un9}(u_{n9}, d_{no})$$

$$(257) \quad C_{no} = C^n * c'_{Cn,dno}(u_{n9}, d_{no})$$

Input-constrained output supply of oilseed crushing and refining sector

$$(258) \quad C_{n1} = Z^{nc} * r'_{Znc,dn1}(d_{n1}, d_{n2}, d_{n3})$$

$$(259) \quad C_{n2} = Z^{nc} * r'_{Znc,dn2}(d_{n1}, d_{n2}, d_{n3})$$

$$(260) \quad C_{n3} = Z^{nc} * r'_{Znc,dn3}(d_{n1}, d_{n2}, d_{n3})$$

Equilibrium conditions of oilseed crushing and refining sector

$$(261) \quad Z^{nc}(Z_{n9}, C_{no}) = C^n(C_{n1}, C_{n2}, C_{n3})$$

$$(262) \quad c_{Cn}(u_{n9}, d_{no}) = r_{Znc}(d_{n1}, d_{n2}, d_{n3})$$

Domestic demand of oilseed crushing and refining sector

$$(263) \quad C_{n2} = C_{n2}(d_{n2}, N_{Cn2})$$

Export demand of oilseed crushing and refining sector

$$(264) \quad C_{n3} = C_{n3}(d_{n3}, N_{Cn3})$$

5.4.2 The Model in Equilibrium Displacement Form

The system given by equations (1) to (264) above defines the equilibrium status in the markets of the three models. These equations represent the structural equilibrium models for the western, southern and northern regions' grains industries in general functional form. In order to examine the impacts of exogenous shocks in the industry, the system 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 equilibrium displacement form is presented in Appendix A. A small percentage change in variable (.) is denoted as $E(.) = \Delta(.)/(.)$. 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 promotions. This method allows for good 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 considered are small and parallel.

5.4.3 Integrability Conditions

Once the EDM system has been expressed in displacement form, the next step is to specify values for the market parameters. These market parameters however, cannot take on any arbitrary value. They must be specified in such a manner such that they satisfy the *integrability conditions*. The integrability conditions consist of two parts. As articulated by Zhao *et al.* (2000b, p.27) and Mounter *et al.* (2008, p.38), integrability conditions are imposed on the market parameters to ensure that: (a) the underlying decision-making preference functions in Equations (5.3.24)-(5.3.32), (5.3.37)-(5.3.45), (5.3.65)-(5.3.82), (5.3.83)-(5.3.100), (5.3.119) and (5.3.121) can be recovered from the demand and supply functions in equations (1) to (264) (mathematical integrability); and (b) the underlying decision-making preference functions satisfy the regularity conditions to be actual cost, revenue, profit and utility functions (economic integrability).

The integrability conditions are especially important when estimating the total economic benefits brought about by exogenous shifts in demand and supply. As noted by Just *et al.* (1982), when there are multiple price effects brought about by the initial shock in the system, there are two methods in which the change in total economic surplus can be measured. The first method involves summing up the economic surplus changes across all affected markets measured off the partial equilibrium demand and supply curves. This allows for welfare analysis as the distribution of the total economic

benefits among the different industry groups can be estimated. The second method involves measuring the total economic surplus directly off the general equilibrium demand and supply curves of the market in which the initial shock occurs. Although this provides a convenient way of capturing the total economic surplus, it cannot provide any information around the distribution of the total economic benefits among the various industry groups. The sum of all the benefits accruing to individual industry groups will be equivalent to estimating the total economic surplus directly off the general equilibrium curves in the intervention market only if the integrability conditions are satisfied.

The method of deriving the integrability conditions involves using the properties that define proper cost, revenue, profit and utility functions to derive the corresponding properties required for the derived demand and supply functions specified in Equations (1) to (264). As market elasticities are applied to the derived demand and supply equations in order to solve the model in displacement form (Equations A.1 to A.264 in Appendix A), once the required properties for the derived demand and supply functions are obtained, this will then inform the implied constraints required for the market elasticities. A brief summary of these integrability conditions is discussed below. The complete mathematical derivation of the integrability conditions is covered in Zhao *et al.* (2000b, pp. 111-119).

Output-Constrained Input Demand

As outlined by Zhao *et al.* (2000b, p.114) and Mounter *et al.* (2008, p.39), the integrability conditions relating the input demand functions to their corresponding cost functions are (i) homogeneity, (ii) symmetry and (iii) concavity. The homogeneity condition requires that the input demand function to be homogeneous of degree zero in input prices. The symmetry condition requires the Allen-Uzawa input substitution elasticities to be symmetric. Finally, the concavity condition requires the Hessian matrix of Allen-Uzawa input substitution elasticities to be negative semi-definite. Specifically, this entails the following (Zhao *et al.*, 2000b, pp.111-114):

$$(5.4.1) \quad \sum_{j=1}^k \tilde{\eta}_{ij}(w, y) = 0 \quad (\text{homogeneity})$$

Where $\tilde{\eta}_{ij}(w, y)$ is the constant-output input demand elasticity of x_i with respect to a change in input price w_j , for $(i = 1, \dots, k)$.

$$(5.4.2) \quad s_i(w, y)\tilde{\eta}_{ij}(w, y) = s_j(w, y)\tilde{\eta}_{ji}(w, y) \quad \text{for } (i, j = 1, \dots, k) \quad (\text{symmetry})$$

Where $s_i(\cdot) = (w_i x_i / C)$ is the cost share of the i th input in total cost for $(i = 1, \dots, k)$.

Concavity requires that the hessian matrix $H_\eta = (\tilde{\eta}_{ij}(w, y))_{k \times k}$ be negative semidefinite as follows:

$$(5.4.3) \quad (-1)^m H_{\eta m} = (-1)^m \begin{vmatrix} \tilde{\eta}_{11} & \tilde{\eta}_{12} & \dots & \tilde{\eta}_{1m} \\ \tilde{\eta}_{21} & \tilde{\eta}_{22} & \dots & \tilde{\eta}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\eta}_{m1} & \tilde{\eta}_{m2} & \dots & \tilde{\eta}_{mm} \end{vmatrix} \geq 0 \quad (m = 1, \dots, k-1) \quad (\text{concavity})$$

Where $H_{\eta m} = |(\tilde{\eta}_{ij}(w, y))_{m \times m}|$ ($m = 1, \dots, k$) is the m th principal minor of H_η . This means that the principal minors of the input demand elasticity matrix H_η alternate in sign between non-positive (when k is odd) and non-negative (when k is even) (Zhao *et al.*, 2000b, p.113).

To introduce elasticities of input substitution in these conditions, the following definition by McFadden (1978, pp.79-80) is used (Zhao *et al.*, 2000b, p.111):

$$(5.4.4) \quad \tilde{\eta}_{ij}(w, y) = s_j(w, y)\sigma_{ij}(w, y) \quad \text{for } (i, j = 1, \dots, k)$$

Where $\sigma_{ij}(w, y)$ is the Allen-Uzawa elasticity of substitution between the i th and j th inputs.

By applying Equation (5.4.4), the previous integrability conditions can re-written as follows (Zhao *et al.*, 2000b, pp.112-113):

$$(5.4.1)' \quad \sum_{j=1}^k s_j(w, y)\sigma_{ij}(w, y) = 0 \quad (\text{homogeneity})$$

$$(5.4.2)' \quad \sigma_{ij}(w, y) = \sigma_{ji}(w, y) \quad \text{for } (i, j = 1, \dots, k) \quad (\text{symmetry})$$

$$(5.4.3)' \quad (-1)^m H_{\sigma m} = (-1)^m \begin{vmatrix} \sigma_{11} & \sigma_{12} & \dots & \sigma_{1m} \\ \sigma_{21} & \sigma_{22} & \dots & \sigma_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{m1} & \sigma_{m2} & \dots & \sigma_{mm} \end{vmatrix} \geq 0 \quad (m = 1, \dots, k-1) \quad (\text{concavity})$$

Input-Constrained Output Supply

As with the output-constrained input demands, the integrability conditions relating the output supply functions to their corresponding revenue functions are: (i) homogeneity, (ii) symmetry and (iii) convexity. The homogeneity condition requires that the output supply function to be homogeneous of degree zero in output prices. The symmetry condition requires the Allen-Uzawa product transformation elasticities to be symmetric. The convexity condition requires the Hessian matrix to be positive semi-definite. Specifically, this entails the following (Zhao *et al.*, 2000b, pp.114-116):

$$(5.4.5) \quad \sum_{j=1}^n \tilde{\epsilon}_{ij}(p, x) = 0 \quad (\text{homogeneity})$$

Where $\tilde{\epsilon}_{ij}(p, x)$ is the constant-input output supply elasticity of y_i with respect to a change in output price p_j , for $(i = 1, \dots, n)$.

$$(5.4.6) \quad \lambda_i(p, x) \tilde{\epsilon}_{ij}(p, x) = \lambda_j(p, x) \tilde{\epsilon}_{ji}(p, x) \quad \text{for } (i, j = 1, \dots, n) \quad (\text{symmetry})$$

Where $\lambda_j(\cdot) = (p_j y_j / R)$ is the revenue share of the j th output in total revenue for $(j = 1, \dots, k)$.

Convexity requires that the hessian matrix $H_\epsilon = (\tilde{\epsilon}_{ij}(p, x))_{n \times n}$ be positive semidefinite as follows:

$$(5.4.7) \quad H_{\epsilon m} = \begin{vmatrix} \tilde{\epsilon}_{11} & \tilde{\epsilon}_{12} & \dots & \tilde{\epsilon}_{1m} \\ \tilde{\epsilon}_{21} & \tilde{\epsilon}_{22} & \dots & \tilde{\epsilon}_{2m} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \tilde{\epsilon}_{m1} & \tilde{\epsilon}_{m2} & \dots & \tilde{\epsilon}_{mm} \end{vmatrix} \geq 0 \quad (m = 1, \dots, n-1) \quad (\text{convexity})$$

Where $H_{\epsilon m} = |(\tilde{\epsilon}_{ij}(w, y))_{m \times m}|$ ($m = 1, \dots, k$) is the m th principal minor of H_ϵ . This means that all principal minors of the output supply elasticity matrix H_ϵ are non-negative (Zhao *et al.*, 2000b, p.116).

To introduce output transformation elasticities in these conditions, the following definition by McFadden (1978, pp.79-80) is used (Zhao *et al.*, 2000b, p.114):

$$(5.4.8) \quad \tilde{\epsilon}_{ij}(p, x) = \lambda_j(p, x) \tau_{ij}(p, x) \quad \text{for } (i, j = 1, \dots, n)$$

Where $\tau_{ij}(p, x)$ is the Allen-Uzawa elasticity of transformation between the i th and j th outputs.

By applying Equation (5.4.8), the previous integrability conditions can be re-written as follows (Zhao *et al.*, 2000b, pp.115-116):

$$(5.4.5)' \quad \sum_{j=1}^n \lambda_j(p, x) \tau_{ij}(p, x) = 0 \quad \text{for } (i = 1, \dots, n) \quad (\text{homogeneity})$$

$$(5.4.6)' \quad \tau_{ij}(p, x) = \tau_{ji}(p, x) \quad \text{for } (i, j = 1, \dots, n) \quad (\text{symmetry})$$

$$(5.4.7)' \quad H_{\tau m} = \begin{vmatrix} \tau_{11} & \tau_{12} & \dots & \tau_{1m} \\ \tau_{21} & \tau_{22} & \dots & \tau_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \tau_{m1} & \tau_{m2} & \dots & \tau_{mm} \end{vmatrix} \geq 0 \quad (m = 1, \dots, n-1) \quad (\text{convexity})$$

Exogenous Input Supplies

For exogenous input supply functions, the only integrability condition that needs to be satisfied is convexity. This is because each exogenous supply equation is the only variable that is derived from the relevant profit function in Equation 5.3.12. Other variables influencing the factor supply are assumed to be exogenous. For this reason, the conditions of homogeneity and symmetry are not relevant. Because of this simplification, the convexity condition only requires that the own-price supply elasticities of the input supply functions be positive (Zhao *et al.*, 2000b, p.117), that is:

$$(5.4.9) \quad \varepsilon_x \geq 0$$

Where:

$$x = X_{wo}, X_{wv}, Y_{w1o}, Y_{w2o}, Y_{w3o}, Y_{w4o}, F_{wo}, S_{wo}, M_{wo}, C_{wo} \quad (\text{western region})$$

$$= X_{so}, X_{sv}, Y_{s1o}, Y_{s2o}, Y_{s3o}, Y_{s4o}, Y_{s5}, Y_{s6}, Y_{s7}, F_{so}, S_{so}, M_{so}, C_{so} \quad (\text{southern region})$$

$$= X_{no}, X_{nv}, Y_{n1o}, Y_{n2o}, Y_{n3o}, Y_{n4o}, F_{no}, S_{no}, M_{no}, C_{no} \quad (\text{northern region})$$

Exogenous Output Demands

For the case of exogenous product demand functions, each export market is assumed to be commodity specific for a particular group of consumers (i.e. wheat, barley, canola and pulses in the export markets are assumed to be non-substitutable). This is supported by the explanation provided in Section 6.3.1. Also, processed grain products destined for export markets are assumed to be non-substitutable to their domestic destined counterparts. Because of this, the only integrability condition that needs to be satisfied is concavity. This is because each exogenous demand equation is the only variable that is derived from its relevant utility function in Equation 5.3.14. No other variables are assumed to influence each exogenous demand equation. For this reason, the conditions of homogeneity and symmetry are not relevant. Because of this simplification, the convexity condition only requires that the own-price elasticities of the output demand functions be negative (Zhao *et al.*, 2000b, p.119), that is:

$$(5.4.10) \quad \eta_x \leq 0$$

Where:

$$\begin{aligned} x &= Z_{w1}, Z_{w2}, Z_{w3}, Z_{w4}, F_{w1}, S_{w1}, S_{w2}, M_{w1}, M_{w2}, C_{w2}, C_{w3} && (\text{western region}) \\ &= Z_{s1}, Z_{s2}, Z_{s3}, Z_{s4}, F_{s1}, S_{s1}, S_{s2}, M_{s1}, M_{s2}, C_{s2}, C_{s3} && (\text{southern region}) \\ &= Z_{n1}, Z_{n2}, Z_{n3}, Z_{n4}, Z_{11}, Z_{12}, Z_{13}, F_{n1}, S_{n1}, S_{n2}, M_{n1}, M_{n2}, C_{n2}, C_{n3} && (\text{northern region}) \end{aligned}$$

5.4.4 Imposing the Integrability Conditions on the Model

The homogeneity and symmetry integrability conditions are imposed on the EDMs specified in Equations A.1 to A.264. Consequentially, the EDMs are re-written in Equations B.1 to B.264 in Appendix B, with the inclusion of these two integrability conditions along with the elasticities of input substitution (σ_{ij}) and output transformation (τ_{ij}). The concavity and convexity conditions are satisfied by the appropriate selection of values for the exogenous input supply and output demand elasticities outlined in Chapter 6.

5.5 Summary

In this chapter, the conceptual structure of the Australian grains industry is presented along with the mathematical specification of the EDM system. The industry is represented by three standalone EDMs, one for each agroecological region as defined by the GRDC—western, southern and northern. The model system in its entirety consists of 264 equations with 69 exogenous shifter variables. Each regional EDM is disaggregated both vertically and horizontally, to allow for the distributional impacts towards the various industry groups to be examined.

Horizontally, each region's industry sector produces a number of different outputs along each segments of the supply chain. At the upstream level, farm production is modelled as producing the four grain commodities representative of a standard cropping sequence. The model assumes that all grain from farm production is received and stored up-country. At the storage and handling stage, grains can be exported overseas or sent for secondary processing, through which multiple end products are produced for either export or domestic use. Additionally, inter-regional grain movements are assumed to take place, with the southern region receiving grain inflows from the northern region.

Vertically, the industry supply chain is disaggregated into farm production, storage, processing (milling, stockfeed manufacturing, malt manufacturing, oilseed crushing and refining), along with the export and domestic markets.

The structural model is specified in general functional form in Equations (1) to (264) in Section 5.4.1. The general function form equations are totally differentiated to percentage change form in order to derive the actual equilibrium displacement models outlined in (Equations A.1) to (A.264) in Appendix A. Integrability conditions are then imposed on the equilibrium displacement models, with the final specification of the model presented in Equations (B.1) to (B.264) in Appendix B.

Chapter 6 Input Data, Exogenous Shifts and Economic Surplus Measurements

6.1 Introduction

The objective of the EDM approach is to estimate the resulting changes in all prices and quantities caused by some exogenous shift and thereby calculate the welfare implications of that shift. To achieve this, three types of data are required: (i) initial equilibrium price and quantity values for all sectors of the model; (ii) market elasticities; and (iii) values specified for the exogenous shift variables for all simulated scenarios. This section provides these sets of data.

Section 6.2 specifies the base equilibrium prices and quantities for grain and grain products along each segment of the supply chain for each region. Section 6.3 provides a review and discussion of the various market elasticities reflecting the nature of the Marshallian demand, factor supply, input substitution and output transformation processes in each market. Point estimates based on a combination of published estimates and subjective judgements are then chosen for the purposes of running the base model. Section 6.4 defines the exogenous shift variables for the eight hypothetical RD&E investment scenarios examined for each region. Section 6.5 provides a brief discussion on measuring economic surplus change and specifies the formulas required in their calculations.

6.2 Prices and Quantities

Price and quantity data for each sector of the industry was obtained from a combination of different sources, including Australian Crop Forecasters, ABARES, AEGIC, Rural Bank, JCS Solutions, IBISWorld, industry experts, and subjective judgements. These were discussed in Chapters 3 and 4. Base equilibrium values for crop production were specified as the mean prices and quantities reported by the Australian Crop Forecasters and ABARES between the five year interval of 2011-12 to 2015-16. Calibrating the model using medium run average figures as such, smooths out atypical observations that may be present in any single year. This data period will not be impacted by the structural effects of the regulated single-desk wheat marketing arrangements that were in existence prior to 2008. Tables 6.1, 6.2 and 6.3 provide summaries of the average base equilibrium prices and quantities and associated cost and revenue shares for the industry sectors in each of the three regions.

6.2.1 Western Region

Table 6.1 Western Region base equilibrium prices, quantities, cost shares and revenue shares

	Quantity (000' tonnes)	Price (\$/tonne)	Total Value (\$m)	Cost Shares	Revenue Shares
Farm Production	$Y_{w1} = 8,896$	$v_{w1} = 253$	$TV_{Yw1} = 2,253$	$\kappa_{Xwv} = 0.66$	$\lambda_{Yw1} = 0.62$
	$Y_{w2} = 2,921$	$v_{w2} = 187$	$TV_{Yw2} = 547$	$\kappa_{Xwo} = 0.34$	$\lambda_{Yw2} = 0.15$
	$Y_{w3} = 1,434$	$v_{w3} = 504$	$TV_{Yw3} = 723$		$\lambda_{Yw3} = 0.20$
	$Y_{w4} = 476$	$v_{w4} = 279$	$TV_{Yw4} = 133$		$\lambda_{Yw4} = 0.03$
Up-Country	$Z_{w1} = 8,367$	$u_{w1} = 310$	$TV_{Zw1} = 2,593$	$\kappa_{Yw1o} = 0.17$	$\lambda_{Zw1} = 0.95$
Storage - Wheat	$Z_{w5} = 205$	$u_{w5} = 288$	$TV_{Zw5} = 59$	$\kappa_{Yw1} = 0.83$	$\lambda_{Zw5} = 0.02$
	$Z_{w6} = 323$	$u_{w6} = 222$	$TV_{Zw6} = 72$		$\lambda_{Zw6} = 0.03$
Up-Country	$Z_{w2} = 2,545$	$u_{w2} = 265$	$TV_{Zw2} = 674$	$\kappa_{Yw2o} = 0.29$	$\lambda_{Zw2} = 0.15$
Storage - Barley	$Z_{w7} = 122$	$u_{w7} = 243$	$TV_{Zw7} = 30$	$\kappa_{Yw2} = 0.72$	$\lambda_{Zw7} = 0.01$
	$Z_{w8} = 255$	$u_{w8} = 240$	$TV_{Zw8} = 61$		$\lambda_{Zw8} = 0.01$
Up-Country	$Z_{w3} = 1,375$	$u_{w3} = 561$	$TV_{Zw3} = 771$	$\kappa_{Yw3o} = 0.10$	$\lambda_{Zw3} = 0.96$
Storage - Canola	$Z_{w9} = 59$	$u_{w9} = 539$	$TV_{Zw9} = 32$	$\kappa_{Yw3} = 0.90$	$\lambda_{Zw9} = 0.04$
Up-Country	$Z_{w4} = 285$	$u_{w4} = 336$	$TV_{Zw4} = 96$	$\kappa_{Yw4o} = 0.15$	$\lambda_{Zw4} = 0.68$
Storage - Lupins	$Z_{w10} = 143$	$u_{w10} = 314$	$TV_{Zw10} = 45$	$\kappa_{Yw4} = 0.85$	$\lambda_{Zw10} = 0.32$
Flour Milling	$F_{w1} = 159$	$g_{w1} = 620$	$TV_{Fw1} = 99$	$\kappa_{Fwo} = 0.47$	$\lambda_{Fw1} = 0.89$
	$F_{w2} = 46$	$g_{w2} = 270$	$TV_{Fw2} = 12$	$\kappa_{Zw5} = 0.53$	$\lambda_{Fw2} = 0.11$
Stockfeed	$S_{w1} = 200$	$t_{w1} = 402$	$TV_{Sw1} = 80$	$\kappa_{Sw0} = 0.36$	$\lambda_{Sw1} = 0.31$
Manufacturing	$S_{w2} = 467$	$t_{w2} = 380$	$TV_{Sw2} = 177$	$\kappa_{Zw6} = 0.28$	$\lambda_{Sw2} = 0.69$
				$\kappa_{Zw7} = 0.11$	
				$\kappa_{Zw10} = 0.17$	
				$\kappa_{Fw2} = 0.05$	
				$\kappa_{Cw1} = 0.03$	
Malt	$M_{w1} = 183$	$n_{w1} = 530$	$TV_{Mw1} = 97$	$\kappa_{Mwo} = 0.49$	$\lambda_{Mw1} = 0.81$
Manufacturing	$M_{w2} = 46$	$n_{w2} = 508$	$TV_{Mw2} = 23$	$\kappa_{Zw8} = 0.51$	$\lambda_{Mw2} = 0.19$
Oilseed Crushing and Refining	$C_{w1} = 33$	$d_{w1} = 220$	$TV_{Cw1} = 7$	$\kappa_{Cwo} = 0.12$	$\lambda_{Cw1} = 0.20$
	$C_{w2} = 12$	$d_{w2} = 1,150$	$TV_{Cw2} = 14$	$\kappa_{Zw9} = 0.88$	$\lambda_{Cw2} = 0.38$
	$C_{w3} = 13$	$d_{w3} = 1,128$	$TV_{Cw3} = 14$		$\lambda_{Cw3} = 0.41$

6.2.2 Southern Region

Table 6.2 Southern region base equilibrium prices, quantities, cost shares and revenue shares

	Quantity (000' tonnes)	Price (\$/tonne)	Total Value (\$m)	Cost Shares	Revenue Shares
Farm Production	$Y_{s1} = 7,306$	$v_{s1} = 217$	$TV_{Ys1} = 1,588$	$\kappa_{Xsv} = 0.67$	$\lambda_{Ys1} = 0.57$
	$Y_{s2} = 3,566$	$v_{s2} = 179$	$TV_{Ys2} = 640$	$\kappa_{Xso} = 0.34$	$\lambda_{Ys2} = 0.23$
	$Y_{s3} = 1,053$	$v_{s3} = 468$	$TV_{Ys3} = 493$		$\lambda_{Ys3} = 0.18$
	$Y_{s4} = 190$	$v_{s4} = 347$	$TV_{Ys4} = 66$		$\lambda_{Ys4} = 0.02$
Up-Country Storage - Wheat	$Z_{s1} = 6,522$	$u_{s1} = 288$	$TV_{Zs1} = 1,880$	$\kappa_{Ys1o} = 0.20$	$\lambda_{Zs1} = 0.80$
	$Z_{s5} = 665$	$u_{s5} = 267$	$TV_{Zs5} = 177$	$\kappa_{Ys1} = 0.68$	$\lambda_{Zs5} = 0.76$
	$Z_{s6} = 1,262$	$u_{s6} = 224$	$TV_{Zs6} = 283$	$\kappa_{Y5} = 0.12$	$\lambda_{Zs6} = 0.12$
Up-Country Storage - Barley	$Z_{s2} = 2,397$	$u_{s2} = 260$	$TV_{Zs2} = 624$	$\kappa_{Ys2o} = 0.27$	$\lambda_{Zs2} = 0.66$
	$Z_{s7} = 923$	$u_{s7} = 229$	$TV_{Zs7} = 211$	$\kappa_{Ys2} = 0.68$	$\lambda_{Zs7} = 0.22$
	$Z_{s8} = 357$	$u_{s8} = 254$	$TV_{Zs8} = 109$	$\kappa_{Y6} = 0.05$	$\lambda_{Zs8} = 0.12$
Up-Country Storage - Canola	$Z_{s3} = 903$	$u_{s3} = 539$	$TV_{Zs3} = 487$	$\kappa_{Ys3o} = 0.74$	$\lambda_{Zs3} = 0.74$
	$Z_{s9} = 339$	$u_{s9} = 518$	$TV_{Zs9} = 175$	$\kappa_{Ys3} = 0.11$	$\lambda_{Zs9} = 0.26$
				$\kappa_{Y7} = 0.15$	
Up-Country Storage - Peas	$Z_{s4} = 102$	$u_{s4} = 418$	$TV_{Zs4} = 42$	$\kappa_{Ys4o} = 0.15$	$\lambda_{Zs4} = 0.55$
	$Z_{s10} = 102$	$u_{s10} = 418$	$TV_{Zs10} = 34$	$\kappa_{Ys4} = 0.85$	$\lambda_{Zs10} = 0.45$
Flour Milling	$F_{s1} = 785$	$g_{s1} = 620$	$TV_{Fs1} = 320$	$\kappa_{Fso} = 0.51$	$\lambda_{Fs1} = 0.89$
	$F_{s2} = 228$	$g_{s2} = 270$	$TV_{Fs2} = 40$	$\kappa_{Zs5} = 0.49$	$\lambda_{Fs2} = 0.11$
Stockfeed	$S_{s1} = 785$	$t_{s1} = 401$	$TV_{ss1} = 315$	$\kappa_{Sso} = 0.40$	$\lambda_{Ss1} = 0.31$
Manufacturing	$S_{s2} = 1,831$	$t_{s2} = 380$	$TV_{ss2} = 696$	$\kappa_{Zs6} = 0.28$	$\lambda_{Ss2} = 0.69$
				$\kappa_{Zs7} = 0.21$	
				$\kappa_{Zs10} = 0.03$	
				$\kappa_{Fs2} = 0.04$	
				$\kappa_{Cs1} = 0.04$	
Malt Manufacturing	$M_{s1} = 309$	$n_{s1} = 530$	$TV_{Ms1} = 164$	$\kappa_{Mso} = 0.46$	$\lambda_{Ms1} = 0.81$
	$M_{s2} = 77$	$n_{s2} = 509$	$TV_{Ms2} = 39$	$\kappa_{Zs8} = 0.54$	$\lambda_{Ms2} = 0.19$
Oilseed Crushing and Refining	$C_{s1} = 194$	$d_{s1} = 220$	$TV_{Cs1} = 43$	$\kappa_{Cso} = 0.16$	$\lambda_{Cs1} = 0.20$
	$C_{s2} = 69$	$d_{s2} = 1150$	$TV_{Cs2} = 79$	$\kappa_{Zs9} = 0.84$	$\lambda_{Cs2} = 0.38$
	$C_{s3} = 76$	$d_{s3} = 1129$	$TV_{Cs3} = 86$		$\lambda_{Cs3} = 0.41$

6.2.3 Northern Region

Table 6.3 Northern region base equilibrium prices, quantities, cost shares and revenue shares

	Quantity (000' tonnes)	Price (\$/tonne)	Total Value (\$m)	Cost Shares	Revenue Shares
Farm Production	$Y_{n1} = 8,090$	$v_{n1} = 236$	$TV_{Yn1} = 1,905$	$\kappa_{Xnv} = 0.66$	$\lambda_{Yn1} = 0.63$
	$Y_{n2} = 1,571$	$v_{n2} = 217$	$TV_{Yn2} = 341$	$\kappa_{Xno} = 0.34$	$\lambda_{Yn2} = 0.11$
	$Y_{n3} = 938$	$v_{n3} = 475$	$TV_{Yn3} = 445$		$\lambda_{Yn3} = 0.15$
	$Y_{n4} = 642$	$v_{n4} = 485$	$TV_{Yn4} = 311$		$\lambda_{Yn4} = 0.10$
Up-Country	$Z_{n1} = 3,213$	$u_{n1} = 305$	$TV_{Zn1} = 981$	$\kappa_{Yn1o} = 0.14$	$\lambda_{Zn1} = 0.44$
Storage - Wheat	$Z_{n5} = 1,894$	$u_{n5} = 284$	$TV_{Zn5} = 538$	$\kappa_{Yn1} = 0.86$	$\lambda_{Zn5} = 0.24$
	$Z_{n6} = 1,840$	$u_{n6} = 229$	$TV_{Zn6} = 422$		$\lambda_{Zn6} = 0.19$
					$\lambda_{Zn11} = 0.13$
Up-Country	$Z_{n2} = 273$	$u_{n2} = 287$	$TV_{Zn2} = 78$	$\kappa_{Yn2o} = 0.19$	$\lambda_{Zn2} = 0.19$
Storage - Barley	$Z_{n7} = 891$	$u_{n7} = 264$	$TV_{Zn7} = 235$	$\kappa_{Yn2} = 0.81$	$\lambda_{Zn7} = 0.56$
	$Z_{n8} = 224$	$u_{n8} = 267$	$TV_{Zn8} = 59$		$\lambda_{Zn8} = 0.14$
					$\lambda_{Zn12} = 0.12$
Up-Country	$Z_{n3} = 342$	$u_{n3} = 544$	$TV_{Zn3} = 186$	$\kappa_{Yn3o} = 0.11$	$\lambda_{Zn3} = 0.37$
Storage - Canola	$Z_{n9} = 408$	$u_{n9} = 523$	$TV_{Zn9} = 213$	$\kappa_{Yn3} = 0.89$	$\lambda_{Zn9} = 0.43$
					$\lambda_{Zn13} = 0.19$
Up-Country	$Z_{n4} = 102$	$u_{n4} = 418$	$TV_{Zn4} = 42$	$\kappa_{Yn4o} = 0.09$	$\lambda_{Zn4} = 0.96$
Storage - Chickpeas	$Z_{n10} = 102$	$u_{n10} = 418$	$TV_{Zn10} = 34$	$\kappa_{Yn4} = 0.91$	$\lambda_{Zn10} = 0.04$
Flour Milling	$F_{n1} = 1,452$	$g_{n1} = 620$	$TV_{Fn1} = 900$	$\kappa_{Fno} = 0.47$	$\lambda_{Fn1} = 0.88$
	$F_{n2} = 442$	$g_{n2} = 270$	$TV_{Fn2} = 119$	$\kappa_{Zn5} = 0.53$	$\lambda_{Fn2} = 0.12$
Stockfeed	$S_{n1} = 1,022$	$t_{n1} = 403$	$TV_{Sn1} = 411$	$\kappa_{Sno} = 0.37$	$\lambda_{Sn1} = 0.31$
Manufacturing	$S_{n2} = 2,384$	$t_{n2} = 380$	$TV_{Sn2} = 906$	$\kappa_{Zn6} = 0.32$	$\lambda_{Sn2} = 0.69$
				$\kappa_{Zn7} = 0.18$	
				$\kappa_{Zn10} = 0.01$	
				$\kappa_{Fn2} = 0.09$	
				$\kappa_{Cn1} = 0.04$	
Malt	$M_{n1} = 161$	$n_{n1} = 530$	$TV_{Mn1} = 85$	$\kappa_{Mno} = 0.44$	$\lambda_{Mn1} = 0.81$
Manufacturing	$M_{n2} = 40$	$n_{n2} = 507$	$TV_{Mn2} = 20$	$\kappa_{Zn8} = 0.56$	$\lambda_{Mn2} = 0.19$
Oilseed Crushing and Refining	$c_{n1} = 233$	$d_{n1} = 220$	$TV_{Cn1} = 51$	$\kappa_{Cno} = 0.15$	$\lambda_{Cn1} = 0.20$
	$c_{n2} = 83$	$d_{n2} = 1150$	$TV_{Cn2} = 96$	$\kappa_{Cn9} = 0.85$	$\lambda_{Cn2} = 0.38$
	$c_{n3} = 92$	$d_{n3} = 1127$	$TV_{Cn3} = 103$		$\lambda_{Cn3} = 0.41$

6.3 Market Parameters

An EDM uses estimates of elasticities of supply and demand for each market segment of the industry. These estimates reflect the nature of the demand, supply, input substitution and product transformation processes in each market segment. These elasticities describe the market responsiveness of quantity variables to price changes. Obtaining empirical estimates of elasticities is one of the most crucial aspects of an EDM. Results are typically highly sensitive to different elasticity values, leading to different conclusions.

The values of elasticities of supply and demand can be derived from economic theory, or from existing econometric estimations or from expert opinion. Robust estimates of many elasticities are difficult to obtain. Many studies rely on expert opinion and subjective judgements about price elasticities of supply and demand. Estimates of agricultural elasticities vary substantially because of geographic coverage, length of run, sample periods, estimation method, functional form, and explanatory variables used in the estimation process (Griffith & l'Anson, 2001).

In addition, the magnitudes of price elasticities of supply and demand depend largely on where the elasticity is being measured in the value chain. For instance, marketing intermediaries such as processors and retailers have their own production technologies and will also respond to changes in relative prices. This affects consumer demand in the value chain, to the extent where it is unlikely the derived demand elasticities for the primary product will match consumer demand (Asche *et al.*, 2002; Hartmann *et al.*, 2001). For instance, price elasticities of supply and demand at the farm gate tend to be lower than those measured at retail (Maclaren, 1995). Elasticity estimates are not readily available for all stages in the value chain. Most price elasticities reviewed are measures of consumer demand using price data at the retail level. Estimates of price elasticities for all stages in the value chain are difficult to find.

These elasticity values need to satisfy the concavity and convexity conditions for integrability for all demand and supply functions in the model. The approach used in this study to obtain elasticity values closely follows that of Zhao *et al.* (2000b, p. 27).

6.3.1 Demand Elasticities

Domestic

Estimates for own-price and cross-price elasticities of demand are required to represent demand in the domestic markets of the EDM. Own-price elasticities of demand indicate the degree to which buyers respond to purchases of a particular product as the price of that product rises or falls. The steepness of the demand curve visually represents the elasticity of demand for a grain commodity, and changes in quantity demanded to changes in own-prices can be depicted as movements along a demand curve.

The model structure presented in this paper, does not require information on domestic own price elasticities of demand at the farm gate level. A few past studies have estimated own price elasticities of demand for grain products. Ulubasoglu *et al.* (2015) estimated the own-price elasticity of demand for bread in Australian households to be -0.733. Since bread is further up the value chain than flour, it is logical to assume that the domestic own-price elasticity of demand for flour would be more inelastic than this value. An earlier study by Seale *et al.* (2003), used a different data sample and methodology, and they estimated the own-price elasticity of demand for bread to be lower at -0.115.

Based on these past studies, an estimated value of -0.5 was chosen for the own price elasticity of demand for flour in the base model for each region. Similarly, the own-price elasticity of domestic demand for the other processed grain products—stockfeed, malt and canola oil have also been assigned a value of -0.5. Each of these processed grain products have distinctive uses and cannot be easily substituted. For instance, domestic flour is primarily used for human consumption and industrial uses whereas domestic stockfeed is used for livestock. Therefore, it is assumed that each of these processed products are own-price dependent only with their cross-price elasticities set to zero.

Export

Studies examining export demand elasticities for Australian grains are scarce. Australian grain sellers on export markets are largely regarded as being price takers (Alston *et al.*, 2004). The consensus is that export demand is price elastic.

Jomini *et al.* (1994) provided a series of parameter estimates used in the calibration of the Industry Commission's SALTER global trade model. The elasticity values differed depending on the destination region. Table 6.4 is a summary of these estimates of price elasticities. Based on these estimates, a value of -5.0 has been specified for the export demand elasticity for wheat, barley, canola and peas in the base model for each region, implying that any changes in export quantities will only have a minor influence on export prices as commodity prices are largely determined by the world market.

For the case of export stockfeed, malt and canola, there is a higher degree of product differentiation for these processed grain products compared to primary grains. However, as Australia's world market share is small for each of these products, a best-guess value of -4.0 has been assigned for the export demand elasticities of these processed grain products.

As with the case in the domestic markets, processed grain products destined for export markets are also assumed to exhibit zero substitutability due to their specificity in use and customer base.

In terms of raw grain exports, it can be seen from Section 3.3 that the major export destinations are different for each grain commodity. For instance, the chief export destination for wheat is Indonesia accounting for around 22% of total wheat export value. On the other hand, China is Australia's largest barley export market accounting for 59% of total barley export value. The European Union is the leading destination for canola exports taking over 70% of the total value, and the Indian sub-continent is the leading destination for pulses accounting for around two-thirds of the total export value. Because of this, it is assumed that raw grain exports are primarily sold in different export markets and as such, are own-price dependent only (zero cross-price elasticities).

Table 6.4 Australian export demand elasticities by commodity and destination region

	Wheat	Other Grains
New Zealand	-1.5	-3.3
Canada	-4.4	-4.4
United States	-4.4	-4.4
Japan	-3.8	-4.2
Korea	-4.2	-4.4
European Union	-4.4	-4.4
Indonesia	-2.1	-4.4
Malaysia	-1.7	-4.3
Philippines	-4.4	-4.1
Singapore	-2.1	-4.3
Thailand	-3.1	-2.9
China	-4.1	-3.1
Hong Kong	-4.4	-4.4
Taiwan	-4.4	-4.1
Rest of world	-4.0	-4.4

Source: Jomini, McDougall, Watts & Dee (1994)

6.3.2 Input Supply Elasticities

In an EDM, price elasticities of supply for exogenous inputs are needed in each sector of the model. Factor inputs exogenous to the EDM include land, labour, capital and fertiliser. In most instances, only own-price elasticities of supply are required in the EDM. The own-price elasticity of supply for factor inputs indicates how much the supply of the factor input changes in response to a change in the price of the input. There are few empirical estimates of these factor inputs in Australian agriculture. Most previous EDM studies have aggregated these production inputs into one group and assumed these inputs to be non-specialised and therefore highly elastic in supply (Mounter *et al.*, 2008).

Based on limited empirical studies and subjective judgement, Zhao *et al.* (2003) disaggregated factor supply elasticities in the Australian wine industry into two groups of inputs – capital and mobile factors. Both short run and long run adjustment periods were provided for these input elasticities. Capital factor inputs are specialised inputs such as fixed capital and human capital with relatively inelastic supplies. These inputs were estimated to have price elasticities of supply of 0.4 in the short run and 1.0 in the long run. Mobile factor inputs on the other hand are those inputs non-specific to the wine industry and include factors such as labour and chemicals. These inputs are more elastic in supply and

were estimated to be 5.0 in both the short and long run. These results are largely consistent with Salhofer's (2000) review of various studies on agricultural factor supply elasticities in European countries. It was concluded in this review that a plausible range of own-price land supply elasticities was between 0.1 and 0.4. On the other hand, purchased inputs that included fertiliser, pesticides, fuel energy, were found to be elastic in supply, with a plausible range from 1.0 to 5.0.

Empirical evidence is yet to provide consensus on elasticities for labour supply in agriculture in wealthy countries. This is especially difficult to model given the income and substitution present in farm labour supply. Salhofer (2000) suggested that a plausible range of on-farm labour supply elasticities for farm families in Europe was between 0.1 and 1.0 depending on the time, with a plausible base value being 0.5. Other studies suggest the elasticity of labour supply is negative in some cases, meaning that an income effect can sometimes exceed the substitution effect (Linde-Rahr, 2001). Garnett and Lewis (2002) constructed a model of rural labour supply where supply of hired labour depended on the earnings of agriculture relative to earnings in retail and on the unemployment rate in non-metropolitan Australia relative to metropolitan Australia. They found the supply of hired farm labour was elastic with respect to relative wages, with elasticity of supply of hired labour depending on relative employment conditions.

In this EDM, a value of 2.0 has been assigned for the input supply elasticity for variable inputs, and a value of 1.0 has been assigned for the input supply elasticity of other non-variable inputs for the farm production sector. A higher value of 2.5 has been assigned for the input factor supply elasticity in the storage sector due to the assumption that these factor inputs are non-specialised. On the other hand, it is assumed that the flour milling, stockfeed manufacturing, malting, and oilseed crushing and refining sectors require the use of capital-intensive and highly specialised equipment. Because of this, a value of 1.5 has been assigned for the input factor supply elasticity for flour milling, and a value of 1.0 has been assigned to the input factor supply elasticities in the stockfeed manufacturing, malting, and oilseed crushing and refining sectors.

6.3.3 Input Substitution Elasticities

Input substitution matters when there are multiple inputs in production. In an EDM, the degree of substitution between different inputs in each stage of the marketing chain is measured by the price elasticity of input substitution. Alston and Scobie (1983), commenting on Freebairn *et al.* (1982), argued that the elasticity of substitution of inputs plays a crucial role in the distribution of research

benefits along the value chain of an EDM. In the absence of substitutability among inputs, research-induced cost reductions in one part of the system deliver positive benefits to producers and consumers at all stages of the system. The distribution of benefits is independent of where the shock is applied in the system (Freebairn *et al.*, 1982). Once input substitution is introduced, these results no longer hold; producers will receive larger benefits if a shock occurs in their sector when the elasticity of substitution of inputs increases.

Different measures of input substitutability are given in the literature, including Hicksian direct elasticity, Allen-Uzawa elasticity, Morishima elasticity, and shadow elasticity. In most EDMs, the Allen-Uzawa elasticity has been the preferred method. The approach measures how one input adjusts to a change in factor price, assuming constant output. Incorporating elasticities of input substitution in the model has implications for results. A small degree of input substitution can have a large effect on the distribution of research benefits (Alston and Scobie, 1983).

Sheng *et al.* (2014) used the Hicks-neutral approach to estimate the price elasticity of substitution between inputs. Their approach used farm data from the ABARES's Agriculture and Grazing Industry Survey from 1978 to 2007. The mean values for the elasticities of substitution were estimated to be 0.13 between capital and labour, 1.79 between labour and intermediate inputs, and 1.41 between capital and intermediate inputs.

Salhofer (2000) reviewed 32 studies of agricultural factor substitution across European countries, and concluded that a plausible Allen-Uzawa elasticity of substitution ranged between 0.3 to 1.5 for farm-owned inputs and purchased inputs, from 0.0 to 0.8 for land and other farm-owned inputs, and between 0.0 and 0.1 for different purchased inputs.

Elasticities of input substitution can vary between different agricultural zones because of different production techniques. For example, Dixon *et al.* (1982) point out that high rainfall areas are dominated by small area farms using relatively labour-intensive techniques in contrast to drier zones where these same commodities are produced on much larger area farms using capital-intensive techniques. An EDM that characterises the grains industry in Australia has to accommodate these differences, though doing so is difficult because of the lack of empirical data on substitution elasticities for specific agricultural zones.

In this EDM, a small value of 0.1 has been assigned for the input substitution elasticities between grain related inputs and 'other inputs' for all sectors. A value of 0.1 has also been assigned for the input substitution elasticity between variable and other non-variable farm inputs. In the storage sector, there is a limited degree of substitutability between the input grains coming from farm production for a given level of outputs. Therefore, all input substitution elasticities between grain inputs in this sector have been assigned a value of 0.1. In terms of the grain inputs used to produce stockfeed, it is assumed that there is a higher degree of flexibility in changing the input mix to produce a certain level of stockfeed output. Because of this a value of 0.5 has been assigned for the input substitution elasticities between all grain inputs for the stockfeed manufacturing sector.

6.3.4 Product Transformation Elasticities

Most of Australia's agricultural commodities come from multi-product farms where multiple outputs are produced from the joint use of inputs or production facilities. In an EDM, this is represented by multi-output production functions in the relevant sectors.

A cropping system, for example, is characterised by crop rotations comprising varying mixes of crops grown on a farm area across years and across farm areas in a year. Many crops, to some degree, are substitutes in consumption – for instance, wheat and barley are animal feeds. Other crops are complements because they are interdependent in the crop rotation – for instance, canola is a disease and weed break crop in a rotation with cereal crops. Farmers decide on a mix of crop outputs according to (i) external factors such as relative crop prices, seasonal events such as the timing of the planting window of time, the existing weed burden in a field, the nature of the quality of the soil in the field, as well as balancing risks according to goals to do with income growth and income stability.

Powell and Gruen (1968) defined product transformation elasticity as a measure of the responsiveness of the product-mix ratio to changes in the marginal rate of transformation. In other words, the possibility of changing the output mix in response to relative price changes in outputs for a given level of inputs. Few estimates of this elasticity measure for broadacre agricultural industries have been made, especially for grains. Dixon *et al.* (1982) estimated product transformation elasticities for Australian agricultural products, but most of these estimated elasticities relate to animal production. The only relevant measure for grains was the transformation elasticity between wheat and barley and this was calculated to be -1.01. Powell and Gruen (1967) examined production transformation

relationships in a model with six agricultural products. The partial transformation elasticity between wheat and coarse grains was estimated to be -0.29.

In this EDM model, a value of -1.0 has been assigned to all product transformation elasticities at the farm production level, implying a flexible degree of transformation possibilities between grain outputs.

At the bulk storage level, grains that are identical in terms of quality can be directed either towards the export markets or the domestic markets for secondary processing. It is assumed that there is considerable flexibility in changing the destination or output mix for these grains. Based on this, a value of -3.0 has been assigned for the product transformation elasticities between wheat bound for export markets and wheat bound for domestic milling ($\tau_{Z1,Z5}$), barley bound for export markets and barley bound for domestic stockfeed ($\tau_{Z1,Z7}$), barley bound for export markets and barley bound for domestic malting ($\tau_{Z1,Z8}$), and canola bound for export markets and canola bound for domestic crushing ($\tau_{Z1,Z9}$). Export wheat and wheat used for domestic milling is normally of a higher quality compared to wheat used for domestic stockfeed. Because of this, there is less flexibility for changing the output mix between these two qualities of wheat. Therefore, a value of -0.5 has been assigned for the product transformation elasticities between export wheat and wheat used for domestic stockfeed ($\tau_{Z1,Z6}$), as well as that of domestic wheat used for milling and domestic wheat used for stockfeed ($\tau_{Z5,Z6}$). Similarly, a value of -0.5 has been assigned for the product transformation elasticity between domestic barley used for stockfeed and domestic barley used for malting ($\tau_{Z7,Z8}$). All other transformation elasticities in the bulk storage sector are assigned a value of 0.01.

In the milling sector, it can be assumed that there is a very limited degree of transformation flexibility between millmix as stockfeed input and flour for domestic consumption. A value of 0.01 has been assigned for the product transformation elasticity here.

In the stockfeed and malting sectors, it is assumed that the final processed grain products are homogenous regardless of whether they are destined for the export or domestic market. Therefore a value of -2.0 is assigned for the product transformation elasticity of export and domestic stockfeed ($\tau_{s1,s2}$) and the product transformation elasticity for export and domestic malt ($\tau_{m1,m2}$). The oilseed crushing and refining sector produces both canola oil and canola meal. It is assumed that canola oil is close to homogenous in both the export and domestic markets. A value of -2.0 has been assigned for the product transformation elasticity for export and domestic canola oil ($\tau_{c2,c3}$). On the other hand,

there are very limited possibilities for changing the output mix between canola meal and canola oil for given inputs. Hence, a value of -0.01 has been assigned to the $\tau_{c1,c2}'s$ and $\tau_{c1,c3}'s$.

Tables 6.5 to 6.7 list the elasticity values for the base conditions in each of the three regions considered in this study.

Table 6.5 Western region market elasticity values for the base run

	Demand Elasticities	Supply Elasticities	Input Substitution Elasticities	Product Transformation Elasticities
Farm Production		$\varepsilon_{X_{WV},WV} = 3.0$ $\varepsilon_{X_{W0},W0} = 1.0$	$\sigma_{X_{WV},X_{W0}} = 0.1$	$\tau_{Y_{W1},Y_{W2}} = -3.0$ $\tau_{Y_{W1},Y_{W3}} = -3.0$ $\tau_{Y_{W1},Y_{W4}} = -3.0$ $\tau_{Y_{W2},Y_{W3}} = -3.0$ $\tau_{Y_{W3},Y_{W4}} = -3.0$
Up-country Storage - Wheat	$\eta_{ZW1,uW1} = -5.0$	$\varepsilon_{Y_{W10},V_{W10}} = 2.5$	$\sigma_{Y_{W1},Y_{W10}} = 0.1$	$\tau_{ZW1,ZW5} = -3.0$ $\tau_{ZW1,ZW6} = -0.5$ $\tau_{ZW5,ZW6} = -0.5$
Up-country Storage - Barley	$\eta_{ZW2,uW2} = -5.0$	$\varepsilon_{Y_{W20},V_{W20}} = 2.5$	$\sigma_{Y_{W2},Y_{W20}} = 0.1$	$\tau_{ZW2,ZW7} = -2.0$ $\tau_{ZW2,ZW8} = -2.0$ $\tau_{ZW7,ZW8} = -0.5$
Up-country Storage - Canola	$\eta_{ZW3,uW3} = -5.0$	$\varepsilon_{Y_{W30},V_{W30}} = 2.5$	$\sigma_{Y_{W3},Y_{W30}} = 0.1$	$\tau_{ZW3,ZW9} = -3.0$
Up-country Storage - Lupins	$\eta_{ZW4,uW4} = -5.0$	$\varepsilon_{Y_{W40},V_{W40}} = 2.5$	$\sigma_{Y_{W4},Y_{W40}} = 0.1$	$\tau_{ZW4,ZW10} = -3.0$
Flour Milling	$\eta_{FW1,gW1} = -0.5$	$\varepsilon_{F_{W0},g_{W0}} = 1.5$	$\sigma_{ZW5,F_{W0}} = 0.1$	$\tau_{FW1,F_{W2}} = -0.01$
Stockfeed Manufacturing	$\eta_{SW1,tW1} = -4.0$ $\eta_{SW2,tW2} = -0.5$	$\varepsilon_{S_{W0},t_{W0}} = 1.0$	$\sigma_{ZW6,ZW7} = 0.5$ $\sigma_{ZW6,ZW10} = 0.5$ $\sigma_{ZW6,F_{W2}} = 0.5$ $\sigma_{ZW6,C_{W1}} = 0.5$ $\sigma_{ZW6,S_{W0}} = 0.1$ $\sigma_{ZW7,ZW10} = 0.5$ $\sigma_{ZW7,F_{W2}} = 0.5$ $\sigma_{ZW7,C_{W1}} = 0.5$ $\sigma_{ZW7,S_{W0}} = 0.1$ $\sigma_{ZW10,F_{W2}} = 0.5$ $\sigma_{ZW10,C_{W1}} = 0.5$ $\sigma_{ZW10,S_{W0}} = 0.1$ $\sigma_{F_{W2},C_{W1}} = 0.5$ $\sigma_{F_{W2},S_{W0}} = 0.1$ $\sigma_{C_{W1},S_{W0}} = 0.1$	$\tau_{SW1,S_{W2}} = -2.0$
Malt Manufacturing	$\eta_{SW1,tW1} = -4.0$ $\eta_{SW2,tW2} = -0.5$	$\varepsilon_{M_{W0},n_{W0}} = 1.0$	$\sigma_{ZW8,M_{W0}} = 0.1$	$\tau_{MW1,M_{W2}} = -2.0$
Oilseed Crushing and Refining	$\eta_{CW2,dW2} = -4.0$ $\eta_{CW3,dW3} = -0.5$	$\varepsilon_{C_{W0},d_{W0}} = 1.0$	$\sigma_{ZW9,C_{W0}} = 0.1$	$\tau_{CW1,C_{W2}} = -0.01$ $\tau_{CW1,C_{W3}} = -0.01$ $\tau_{CW2,C_{W3}} = -2.0$

Table 6.6 Southern region market elasticity values for the base

	Demand Elasticities	Supply Elasticities	Input Substitution Elasticities	Product Transformation Elasticities
Farm Production		$\epsilon_{Xsv, wsv} = 3.0$ $\epsilon_{Xso, wso} = 1.0$	$\sigma_{Xsv, Xso} = 0.1$	$\tau_{Ys1, Ys2} = -3.0$ $\tau_{Ys1, Ys3} = -3.0$ $\tau_{Ys1, Ys4} = -3.0$ $\tau_{Ys2, Ys3} = -3.0$ $\tau_{Ys3, Ys4} = -3.0$
Up-country Storage - Wheat	$\eta_{Zs1, us1} = -5.0$	$\epsilon_{Ys10, vs10} = 2.5$ $\epsilon_{Ys5, vs5} = 0.5$	$\sigma_{Ys1, Ys10} = 0.1$ $\sigma_{Ys1, Ys5} = 2$ $\sigma_{Ys5, Ys10} = 0.1$	$\tau_{Zs1, Zs5} = -3.0$ $\tau_{Zs1, Zs6} = -0.5$ $\tau_{Zs5, Zs6} = -0.5$
Up-country Storage - Barley	$\eta_{Zs2, us2} = -5.0$	$\epsilon_{Ys20, vs20} = 2.5$ $\epsilon_{Ys6, vs6} = 0.5$	$\sigma_{Ys2, Ys20} = 0.1$ $\sigma_{Ys2, Ys6} = 2$ $\sigma_{Ys6, Ys20} = 0.1$	$\tau_{Zs2, Zs7} = -2.0$ $\tau_{Zs2, Zs8} = -2.0$ $\tau_{Zs7, Zs8} = -0.5$
Up-country Storage - Canola	$\eta_{Zs3, us3} = -5.0$	$\epsilon_{Ys30, vs30} = 2.5$ $\epsilon_{Ys7, vs7} = 0.5$	$\sigma_{Ys3, Ys30} = 0.1$ $\sigma_{Ys3, Ys7} = 2$ $\sigma_{Ys7, Ys30} = 0.1$	$\tau_{Zs3, Zs9} = -3.0$
Up-country Storage - Peas	$\eta_{Zs4, us4} = -5.0$	$\epsilon_{Ys40, vs40} = 2.5$	$\sigma_{Ys4, Ys40} = 0.1$	$\tau_{Zs4, Zs10} = -3.0$
Flour Milling	$\eta_{Fs1, gs1} = -0.5$	$\epsilon_{Fso, gso} = 1.5$	$\sigma_{Zs5, Fso} = 0.1$	$\tau_{Fs1, Fs2} = -0.01$
Stockfeed Manufacturing	$\eta_{Ss1, ts1} = -4.0$ $\eta_{Ss2, ts2} = -0.5$	$\epsilon_{Sso, tso} = 1.0$	$\sigma_{Zs6, Zs7} = 0.5$ $\sigma_{Zs6, Zs10} = 0.5$ $\sigma_{Zs6, Fs2} = 0.5$ $\sigma_{Zs6, Cs1} = 0.5$ $\sigma_{Zs6, Sso} = 0.1$ $\sigma_{Zs7, Zs10} = 0.5$ $\sigma_{Zs7, Fs2} = 0.5$ $\sigma_{Zs7, Cs1} = 0.5$ $\sigma_{Zs7, Sso} = 0.1$ $\sigma_{Zs10, Fs2} = 0.5$ $\sigma_{Zs10, Cs1} = 0.5$ $\sigma_{Zs10, Sso} = 0.1$ $\sigma_{Fs2, Cs1} = 0.5$ $\sigma_{Fs2, Sso} = 0.1$ $\sigma_{Cs1, Sso} = 0.1$	$\tau_{Ss1, Ss2} = -2.0$
Malt Manufacturing	$\eta_{Ss1, ts1} = -4.0$ $\eta_{Ss2, ts2} = -0.5$	$\epsilon_{Mso, nso} = 1.0$	$\sigma_{Zs8, Mso} = 0.1$	$\tau_{Ms1, Ms2} = -2.0$
Oilseed Crushing and Refining	$\eta_{Cs2, ds2} = -4.0$ $\eta_{Cs3, ds3} = -0.5$	$\epsilon_{Cso, dso} = 1.0$	$\sigma_{Zs9, Cso} = 0.1$	$\tau_{Cs1, Cs2} = -0.01$ $\tau_{Cs1, Cs3} = -0.01$ $\tau_{Cs2, Cs3} = -2.0$

Table 6.7 Northern region market elasticity values for the base

	Demand Elasticities	Supply Elasticities	Input Substitution Elasticities	Product Transformation Elasticities
Farm Production		$\varepsilon_{Xnv,wnv} = 3.0$ $\varepsilon_{Xno,wno} = 1.0$	$\sigma_{Xnv,Xno} = 0.1$	$\tau_{Yn1,Yn2} = -3.0$ $\tau_{Yn1,Yn3} = -3.0$ $\tau_{Yn1,Yn4} = -3.0$ $\tau_{Yn2,Yn3} = -3.0$ $\tau_{Yn3,Yn4} = -3.0$
Up-country Storage - Wheat	$\eta_{Zn1,un1} = -5.0$	$\varepsilon_{Yn10,vn10} = 2.5$	$\sigma_{Yn1,Yn10} = 0.1$	$\tau_{Zn1,Zn5} = -3.0$ $\tau_{Zn1,Zn6} = -0.5$ $\tau_{Zn1,Zn11} = -2.0$ $\tau_{Zn5,Zn6} = -0.5$ $\tau_{Zn5,Zn11} = -2.0$ $\tau_{Zn6,Zn11} = -0.5$
Up-country Storage - Barley	$\eta_{Zn2,un2} = -5.0$	$\varepsilon_{Yn20,vn20} = 2.5$	$\sigma_{Yn2,Yn20} = 0.1$	$\tau_{Zn2,Zn7} = -2.0$ $\tau_{Zn2,Zn8} = -2.0$ $\tau_{Zn2,Zn12} = -3.0$ $\tau_{Zn7,Zn8} = -0.5$ $\tau_{Zn7,Zn12} = -3.0$ $\tau_{Zn8,Zn12} = -2.0$
Up-country Storage - Canola	$\eta_{Zn3,un3} = -5.0$	$\varepsilon_{Yn30,vn30} = 2.5$	$\sigma_{Yn3,Yn30} = 0.1$	$\tau_{Zn3,Zn9} = -3.0$ $\tau_{Zn3,Zn13} = -3.0$ $\tau_{Zn9,Zn13} = -3.0$
Up-country Storage - Chickpeas	$\eta_{Zn4,un4} = -5.0$	$\varepsilon_{Yn40,vn40} = 2.5$	$\sigma_{Yn4,Yn40} = 0.1$	$\tau_{Zn4,Zn10} = -3.0$
Flour Milling	$\eta_{Fn1,gn1} = -0.5$	$\varepsilon_{Fno,gno} = 1.5$	$\sigma_{Zn5,Fno} = 0.1$	$\tau_{Fn1,Fn2} = -0.01$
Stockfeed Manufacturing	$\eta_{Sn1,tn1} = -4.0$ $\eta_{Sn2,tn2} = -0.5$	$\varepsilon_{Sno,tno} = 1.0$	$\sigma_{Zn6,Zn7} = 0.5$ $\sigma_{Zn6,Zn10} = 0.5$ $\sigma_{Zn6,Fn2} = 0.5$ $\sigma_{Zn6,Cn1} = 0.5$ $\sigma_{Zn6,Sno} = 0.1$ $\sigma_{Zn7,Zn10} = 0.5$ $\sigma_{Zn7,Fn2} = 0.5$ $\sigma_{Zn7,Cn1} = 0.5$ $\sigma_{Zn7,Sno} = 0.1$ $\sigma_{Zn10,Fn2} = 0.5$ $\sigma_{Zn10,Cn1} = 0.5$ $\sigma_{Zn10,Sno} = 0.1$ $\sigma_{Fn2,Cn1} = 0.5$ $\sigma_{Fn2,Sno} = 0.1$ $\sigma_{Cn1,Sno} = 0.1$	$\tau_{Sn1,Sn2} = -2.0$
Malt Manufacturing	$\eta_{Sn1,tn1} = -4.0$ $\eta_{Sn2,tn2} = -0.5$	$\varepsilon_{Mno,tno} = 1.0$	$\sigma_{Zn8,Mno} = 0.1$	$\tau_{Mn1,Mn2} = -2.0$
Oilseed Crushing and Refining	$\eta_{Cn2,dn2} = -4.0$ $\eta_{Cn3,dn3} = -0.5$	$\varepsilon_{Cno,dno} = 1.0$	$\sigma_{Zn9,Cno} = 0.1$	$\tau_{Cn1,Cn2} = -0.01$ $\tau_{Cn1,Cn3} = -0.01$ $\tau_{Cn2,Cn3} = -2.0$

6.4 Exogenous Shifts

The entire model system contains 60 exogenous demand and supply shifter variables in total consisting of:

- 18 exogenous shifters (7 supply and 11 demand shifters) in the western region EDM;
- 21 exogenous shifters (10 supply and 11 demand shifts) in the southern region EDM; and
- 21 exogenous shifters (7 supply and 14 demand shifters) in the northern region EDM.

The exogenous supply shift variables represent the impacts of alternative productivity enhancing (i.e. cost-reducing) research scenarios in various industry sectors and the demand shift variables represent successful quality improving investment scenarios in different markets. Improving the quality of grain and grain products results in an increase in consumers' willingness to pay.

This study simulates and evaluates the economic impacts of eight hypothetical investment scenarios. Under each scenario, an exogenous supply or demand shifter variable is shocked by 1% representing successful investments. Each hypothetical investment scenario is simulated for each regional EDM, with the results discussed and compared. The costs involved in the RD&E interventions that give rise to the 1% shifts are not considered in this study. A summary and description of the exogenous shift variables for these eight RD&E investment scenarios are specified in Table 6.8 below.

Table 6.8 Description of the exogenous shift variables for the hypothetical RD&E investment scenarios examined

Scenario 1:	Farm Production Research Western Region: $t_{xwv} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Southern Region: $t_{xsv} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Northern Region: $t_{xnv} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Cost reduction in farm production resulting from new farm technologies or improvements in cropping processes and practices that increase the productivity of variable inputs.
Scenario 2:	Off-farm Storage Research Western Region: $t_{yw10} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Southern Region: $t_{ys10} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Northern Region: $t_{yn10} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Cost reduction in off-farm wheat storage resulting from new farm technologies and processes that reduce storage losses.
Scenario 3:	Flour Milling Research Western Region: $t_{fwo} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Southern Region: $t_{fso} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Northern Region: $t_{fno} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Cost reduction in flour milling resulting from new technologies and improved processing methods.
Scenario 4:	Stockfeed Manufacturing Research Western Region: $t_{swo} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Southern Region: $t_{sso} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Northern Region: $t_{sno} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Cost reduction in stockfeed manufacturing resulting from new technologies and improved production techniques.
Scenario 5:	Export Stockfeed Research Western Region: $n_{sw1} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Southern Region: $n_{ss1} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Northern Region: $n_{sn1} = -0.01$, rest $t_{ij} = 0$ and $n_{ij} = 0$ Increase in the 'willingness to pay' by export stockfeed customers due to quality improvements or promotion.

Scenario 6:	Domestic Stockfeed Research Western Region: $n_{sw2} = -0.01$, rest $t_{()} = 0$ and $n_{()} = 0$ Southern Region: $n_{ss2} = -0.01$, rest $t_{()} = 0$ and $n_{()} = 0$ Northern Region: $n_{sn2} = -0.01$, rest $t_{()} = 0$ and $n_{()} = 0$ Increase in the 'willingness to pay' by domestic stockfeed customers due to quality improvements or promotion.
Scenario 7:	Export Wheat Research Western Region: $n_{zw1} = -0.01$, rest $t_{()} = 0$ and $n_{()} = 0$ Southern Region: $n_{zs1} = -0.01$, rest $t_{()} = 0$ and $n_{()} = 0$ Northern Region: $n_{zn1} = -0.01$, rest $t_{()} = 0$ and $n_{()} = 0$ Increase in the 'willingness to pay' by export wheat customers due to quality improvements or promotion.
Scenario 8:	Export Barley Research Western Region: $n_{zw2} = -0.01$, rest $t_{()} = 0$ and $n_{()} = 0$ Southern Region: $n_{zs2} = -0.01$, rest $t_{()} = 0$ and $n_{()} = 0$ Northern Region: $n_{zn2} = -0.01$, rest $t_{()} = 0$ and $n_{()} = 0$ Increase in the 'willingness to pay' by export barley customers due to quality improvements or promotion.

6.5 Measuring Economic Surplus Changes

By shocking the EDM system defined in Equations (A.1) to (A.264) and obtaining the resulting ‘displacements’ in prices and quantities enables economic surplus changes to be estimated for each RD&E investment scenario. This section provides a brief discussion on measuring economic surplus change and specifies the formulas required in their calculations.

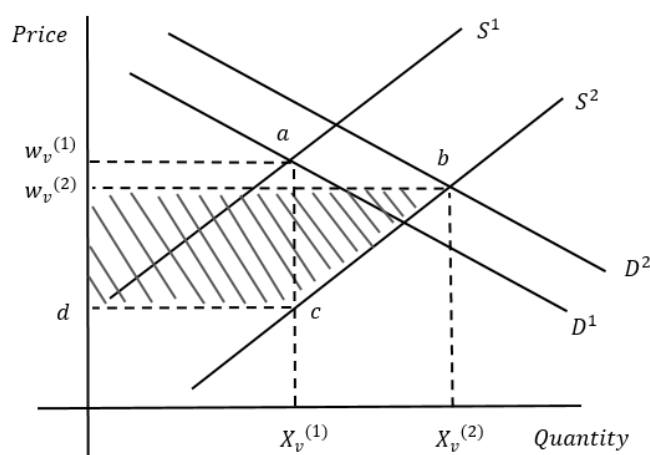
6.5.1 Producers' Surplus Changes for Exogenous Factor Suppliers

As discussed in Section 5.3.4, factor supplies in each market are exogenous to the EDM system due to being a function of their own price and unrelated to other variables. As an example, Figure 6.1 below visually depicts the change in surplus accruing to producers of a particular factor (X_v) in the upstream farm production market as a result of improving technology.

The initial exogenous shock has the initial effect of shifting supply downwards from S^1 to S^2 , leading to a decrease in price. In a single market model the narrative would stop here. However, in a multi-stage production system such as the grains industry, the vertical market relationships need to be taken into consideration. As upstream markets are inputs suppliers to the downstream markets, the decrease in the price of X_v leads to downward shifts in the supply curves of all downstream intermediate and final products, lowering their prices and increasing their quantities. Lower final product prices will raise their demand, which in turn, increases the demand for intermediate products along with factors of production. As a result, the demand curve for X_v shifts upwards from D^1 to D^2 with the new equilibrium point shifting from a to b . Under the assumption of parallel supply and demand shifts, the change in producer surplus is given by the shaded area $(w_v^{(2)}bcd)$ and can be calculated by the formula (Zhao *et al.*, 2000b; Mounter *et al.*, 2008):

$$(6.5.1) \quad \Delta PS_{X_v} = w_v^{(1)} X_v^{(1)} (E w_v - t_{X_v}) (1 + 0.5 EX_v)$$

Where $E w_v = (w_v^{(2)} - w_v^{(1)}) / w_v^{(1)}$ and $EX_v = (X_v^{(2)} - X_v^{(1)}) / X_v^{(1)}$

Figure 6.1 Change in producer surplus for a shock in factor supply ($t_{Xv} = -0.01$)

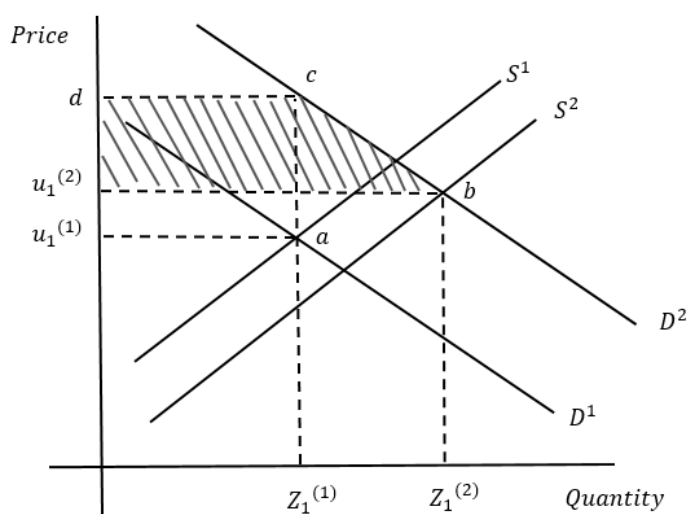
Source: Zhao *et al.* (2000) and Mounter *et al.* (2008)

6.5.2 Consumers' Surplus Changes

To describe how consumer surplus changes are measured using an example, Figure 6.2 below depicts the change in surplus accruing to export consumers of wheat (Z_1). The initial upwards shift in the demand curve from D^1 to D^2 represents an increase in the 'willingness to pay' by overseas consumers as a result of either quality enhancing research or an effective promotion campaign. The higher demand for export wheat subsequently increases the demand for outputs in vertically linked upstream markets, and eventually increases the factor supplies in farm production. This will then trigger downwards shifts of supply in all vertically linked downstream markets, including the supply curve for Z_1 , shifting from S^1 to S^2 . The new equilibrium point has also shifted from a to b . Under the assumption of parallel supply and demand shifts, the change in consumer surplus is given by the shaded area ($u_1^{(2)}bcd$) and can be calculated by the formula (Zhao *et al.*, 2000b; Mounter *et al.*, 2008):

$$(6.5.2) \quad \Delta CS_{Z_1} = u_1^{(1)} Z_1^{(1)} (n_{Z_1} - Eu_1) (1 + 0.5EZ_1)$$

Where $Eu_1 = (u_1^{(2)} - u_1^{(1)})/u_1^{(1)}$ and $EZ_1 = (Z_1^{(2)} - Z_1^{(1)})/Z_1^{(1)}$

Figure 6.2 Change in consumer surplus for a shock in export demand ($n_{Z1} = 0.01$)

Source: Zhao *et al.* (2000) and Mounter *et al.* (2008)

6.5.3 Total Surplus Change and Welfare Impacts

As discussed in Section 5.4.3, there are two alternative approaches that can be used to estimate the total surplus changes in a multi-market model structure such as an EDM. The first approach involves measuring the total surplus change off the general equilibrium demand or supply curves in the market where the initial exogenous shock occurs. This approach is useful in estimating the total benefits brought by RD&E investments, but provides no information around the distribution of the total benefits among the different markets and industry groups. The second approach measures the total surplus changes by summing all the individual surplus changes across all markets which are measured off the partial equilibrium demand and supply curves in each market. This second approach has the advantage in being able to provide the distribution of total benefits among industry participants. Both approaches will be equivalent if the integrability conditions are met.

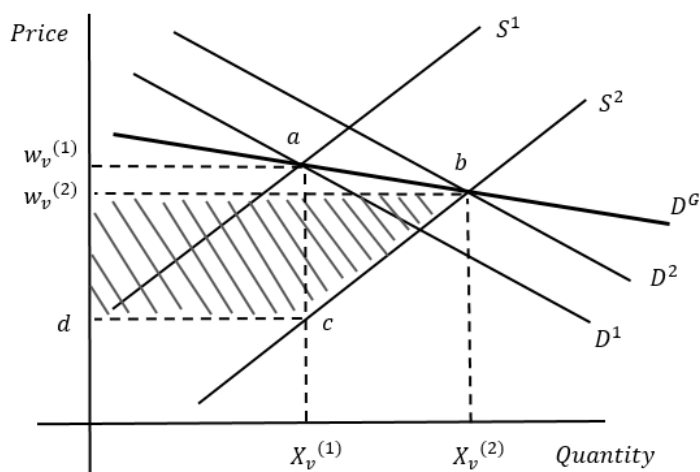
To measure total surplus change using the general equilibrium approach, consider the example depicted under Figure 6.3. This is the same scenario as depicted in Figure 6.1 with the change in surplus accruing to producers of a particular factor (X_v) in the upstream farm production market as a result of improving technology. The general equilibrium demand curve is represented by D^G and is the locus connecting the initial equilibrium point with the post market adjustment equilibrium point. This curve was termed the total demand response function by Buse (1958).

The total surplus measured from the general equilibrium demand curve is the sum of consumer and producer surplus which has already been established as the shaded area bounded by $(w_v^{(2)}bcd)$.

Consumer surplus measured from the general equilibrium curve is measured by the area bounded by $(w_v^{(1)}abw_v^{(2)})$. Therefore the total surplus is captured by the area $(w_v^{(1)}abcd)$ and can be calculated using the formula (Zhao *et al.*, 2000b):

$$(6.5.3) \quad \Delta TS = -w_v^{(1)}X_v^{(1)}t_{Xv}(1 + 0.5EX_v)$$

Figure 6.3 Total surplus change measured from the General Equilibrium curve ($t_{Xv} = -0.01$)



Source: Zhao *et al.* (2000) and Mounter *et al.* (2008)

The formulas used to calculate the economic surplus changes for each industry group by region are presented in Tables 6.6 to 6.8. Summing up the changes to each individual industry group will then provide the total economic surplus change.

The changes in economic surplus are measured off the Marshallian demand and supply curves derived by equations (5.3.120) and (5.3.122). Marshallian curves show the relationship between the price of a good and its quantity demanded, factoring in changes in both income and utility. Hicksian (compensated) curves on the other hand assume a fixed level of utility with only the income effect being taken into account. Using Hicksian curves to measure changes in economic surplus resulting from a policy shock provides a monetary measure that leaves the consumer or producer's utility unchanged. Hicksian curves are widely considered to provide exact measures of welfare change, and is only a concern when measuring consumer surplus, as both Marshallian and Hicksian measures are equivalent when measuring producer surplus (Alston and Larson, 1993). As explained by Zhao *et al.* (2000b, p.66) using the Marshallian curves to approximate the exact Hicksian surplus change measures is appropriate as long as the shifts considered are small (i.e. 1%).

Alternatively, the total economic surplus change can also be calculated directly through the total economic surplus change formulas presented in Table 6.7.

Table 6.4 Formulas used to calculate economic surplus by industry group in Western Region

<u>Factor Producer Surplus Changes</u>	
Farm variables input suppliers	$\Delta PS_{X_{wv}} = w_{wv}^{(1)} X_{wv}^{(1)} (E w_{wv} - t_{X_{wv}}) (1 + 0.5 E X_{wv})$
Farm non-variable input suppliers	$\Delta PS_{X_{wo}} = w_{wo}^{(1)} X_{wo}^{(1)} (E w_{wo} - t_{X_{wo}}) (1 + 0.5 E X_{wo})$
Wheat up-country storage other input suppliers	$\Delta PS_{Y_{w1o}} = v_{w1o}^{(1)} Y_{w1o}^{(1)} (E v_{w1o} - t_{Y_{w1o}}) (1 + 0.5 E Y_{w1o})$
Barley up-country storage other input suppliers	$\Delta PS_{Y_{w2o}} = v_{w2o}^{(1)} Y_{w2o}^{(1)} (E v_{w2o} - t_{Y_{w2o}}) (1 + 0.5 E Y_{w2o})$
Canola up-country storage other input suppliers	$\Delta PS_{Y_{w3o}} = v_{w3o}^{(1)} Y_{w3o}^{(1)} (E v_{w3o} - t_{Y_{w3o}}) (1 + 0.5 E Y_{w3o})$
Lupin up-country storage other input suppliers	$\Delta PS_{Y_{w4o}} = v_{w4o}^{(1)} Y_{w4o}^{(1)} (E v_{w4o} - t_{Y_{w4o}}) (1 + 0.5 E Y_{w4o})$
Milling other input suppliers	$\Delta PS_{F_{wo}} = g_{wo}^{(1)} F_{wo}^{(1)} (E g_{wo} - t_{F_{wo}}) (1 + 0.5 E F_{wo})$
Stockfeed manufacturing other input suppliers	$\Delta PS_{S_{wo}} = t_{wo}^{(1)} S_{wo}^{(1)} (E t_{wo} - t_{S_{wo}}) (1 + 0.5 E S_{wo})$
Malt manufacturing other input suppliers	$\Delta PS_{M_{wo}} = n_{wo}^{(1)} M_{wo}^{(1)} (E n_{wo} - t_{M_{wo}}) (1 + 0.5 E M_{wo})$
Oilseed crushing and refining	$\Delta PS_{C_{wo}} = d_{wo}^{(1)} C_{wo}^{(1)} (E d_{wo} - t_{C_{wo}}) (1 + 0.5 E C_{wo})$
<u>Export Consumer Surplus Changes</u>	
Export wheat consumers	$\Delta CS_{Z_{w1}} = u_{w1}^{(1)} Z_{w1}^{(1)} (n_{Z_{w1}} - E u_{w1}) (1 + 0.5 E Z_{w1})$
Export barley consumers	$\Delta CS_{Z_{w2}} = u_{w2}^{(1)} Z_{w2}^{(1)} (n_{Z_{w2}} - E u_{w2}) (1 + 0.5 E Z_{w2})$
Export canola consumers	$\Delta CS_{Z_{w3}} = u_{w3}^{(1)} Z_{w3}^{(1)} (n_{Z_{w3}} - E u_{w3}) (1 + 0.5 E Z_{w3})$
Export lupin consumers	$\Delta CS_{Z_{w4}} = u_{w4}^{(1)} Z_{w4}^{(1)} (n_{Z_{w4}} - E u_{w4}) (1 + 0.5 E Z_{w4})$
Export stockfeed consumers	$\Delta CS_{S_{w1}} = t_{w1}^{(1)} S_{w1}^{(1)} (n_{S_{w1}} - E t_{w1}) (1 + 0.5 E S_{w1})$

Export malt consumers	$\Delta CS_{Mw1} = n_{w1}^{(1)} M_{w1}^{(1)} (n_{Mw1} - E n_{w1}) (1 + 0.5 E M_{w1})$
Export canola oil consumers	$\Delta CS_{Cw1} = d_{w1}^{(1)} C_{w1}^{(1)} (n_{Cw1} - E d_{w1}) (1 + 0.5 E C_{w1})$
<u>Domestic Consumer Surplus Changes</u>	
Domestic flour consumers	$\Delta CS_{Fw1} = g_{w1}^{(1)} F_{w1}^{(1)} (n_{Fw1} - E g_{w1}) (1 + 0.5 E F_{w1})$
Domestic stockfeed consumers	$\Delta CS_{Sw2} = t_{w2}^{(1)} S_{w2}^{(1)} (n_{Sw2} - E t_{w2}) (1 + 0.5 E S_{w2})$
Domestic malt consumers	$\Delta CS_{Mw2} = n_{w2}^{(1)} M_{w2}^{(1)} (n_{Mw2} - E n_{w2}) (1 + 0.5 E M_{w2})$
Domestic canola oil consumers	$\Delta CS_{Cw2} = d_{w2}^{(1)} C_{w2}^{(1)} (n_{Cw2} - E d_{w2}) (1 + 0.5 E C_{w2})$

Table 6.5 Formulas used to calculate economic surplus by industry group in Southern Region

<u>Factor Producer Surplus Changes</u>	
Farm variables input suppliers	$\Delta PS_{X_{sv}} = w_{sv}^{(1)} X_{sv}^{(1)} (E w_{sv} - t_{X_{sv}}) (1 + 0.5 E X_{sv})$
Farm non-variable input suppliers	$\Delta PS_{X_{so}} = w_{so}^{(1)} X_{so}^{(1)} (E w_{so} - t_{X_{so}}) (1 + 0.5 E X_{so})$
Wheat up-country storage other input suppliers	$\Delta PS_{Y_{s1o}} = v_{s1o}^{(1)} Y_{s1o}^{(1)} (E v_{s1o} - t_{Y_{s1o}}) (1 + 0.5 E Y_{s1o})$
Barley up-country storage other input suppliers	$\Delta PS_{Y_{s2o}} = v_{s2o}^{(1)} Y_{s2o}^{(1)} (E v_{s2o} - t_{Y_{s2o}}) (1 + 0.5 E Y_{s2o})$
Canola up-country storage other input suppliers	$\Delta PS_{Y_{s3o}} = v_{s3o}^{(1)} Y_{s3o}^{(1)} (E v_{s3o} - t_{Y_{s3o}}) (1 + 0.5 E Y_{s3o})$
Peas up-country storage other input suppliers	$\Delta PS_{Y_{s4o}} = v_{s4o}^{(1)} Y_{s4o}^{(1)} (E v_{s4o} - t_{Y_{s4o}}) (1 + 0.5 E Y_{s4o})$
Milling other input suppliers	$\Delta PS_{F_{so}} = g_{so}^{(1)} F_{so}^{(1)} (E g_{so} - t_{F_{so}}) (1 + 0.5 E F_{so})$
Stockfeed manufacturing other input suppliers	$\Delta PS_{S_{so}} = t_{so}^{(1)} S_{so}^{(1)} (E t_{so} - t_{S_{so}}) (1 + 0.5 E S_{so})$
Malt manufacturing other input suppliers	$\Delta PS_{M_{so}} = n_{so}^{(1)} M_{so}^{(1)} (E n_{so} - t_{M_{so}}) (1 + 0.5 E M_{so})$
Oilseed crushing and refining	$\Delta PS_{C_{so}} = d_{so}^{(1)} C_{so}^{(1)} (E d_{so} - t_{C_{so}}) (1 + 0.5 E C_{so})$
<u>Northern Region Producer Surplus Changes</u>	
Northern region grain storage and handlers of wheat	$\Delta PS_{Y_{s5}} = v_{s5}^{(1)} Y_{s5}^{(1)} (E v_{s5} - t_{Y_{s5}}) (1 + 0.5 E Y_{s5})$
Northern region grain storage and handlers of barley	$\Delta PS_{Y_{s6}} = v_{s6}^{(1)} Y_{s6}^{(1)} (E v_{s6} - t_{Y_{s6}}) (1 + 0.5 E Y_{s6})$
Northern region grain storage and handlers of canola	$\Delta PS_{Y_{s7}} = v_{s7}^{(1)} Y_{s7}^{(1)} (E v_{s7} - t_{Y_{s7}}) (1 + 0.5 E Y_{s7})$
<u>Export Consumer Surplus Changes</u>	
Export wheat consumers	$\Delta CS_{Z_{s1}} = u_{s1}^{(1)} Z_{s1}^{(1)} (n_{Z_{s1}} - E u_{s1}) (1 + 0.5 E Z_{s1})$
Export barley consumers	$\Delta CS_{Z_{s2}} = u_{s2}^{(1)} Z_{s2}^{(1)} (n_{Z_{s2}} - E u_{s2}) (1 + 0.5 E Z_{s2})$
Export canola consumers	$\Delta CS_{Z_{s3}} = u_{s3}^{(1)} Z_{s3}^{(1)} (n_{Z_{s3}} - E u_{s3}) (1 + 0.5 E Z_{s3})$

Export lupin consumers	$\Delta CS_{Zs4} = u_{s4}^{(1)} Z_{s4}^{(1)} (n_{Zs4} - E u_{s4}) (1 + 0.5 E Z_{s4})$

Export stockfeed consumers	$\Delta CS_{Ss1} = t_{s1}^{(1)} S_{s1}^{(1)} (n_{Ss1} - E t_{s1}) (1 + 0.5 E S_{s1})$

Export malt consumers	$\Delta CS_{Ms1} = n_{s1}^{(1)} M_{s1}^{(1)} (n_{Ms1} - E n_{s1}) (1 + 0.5 E M_{s1})$

Export canola oil consumers	$\Delta CS_{Cs1} = d_{s1}^{(1)} C_{s1}^{(1)} (n_{Cs1} - E d_{s1}) (1 + 0.5 E C_{s1})$

Domestic Consumer Surplus Changes

Domestic flour consumers	$\Delta CS_{Fs1} = g_{s1}^{(1)} F_{s1}^{(1)} (n_{Fs1} - E g_{s1}) (1 + 0.5 E F_{s1})$

Domestic stockfeed consumers	$\Delta CS_{Ss2} = t_{s2}^{(1)} S_{s2}^{(1)} (n_{Ss2} - E t_{s2}) (1 + 0.5 E S_{s2})$

Domestic malt consumers	$\Delta CS_{Ms2} = n_{s2}^{(1)} M_{s2}^{(1)} (n_{Ms2} - E n_{s2}) (1 + 0.5 E M_{s2})$

Domestic canola oil consumers	$\Delta CS_{Cs2} = d_{s2}^{(1)} C_{s2}^{(1)} (n_{Cs2} - E d_{s2}) (1 + 0.5 E C_{s2})$

Table 6.6 Formulas used to calculate economic surplus by industry group in Northern Region

<u>Factor Producer Surplus Changes</u>	
Farm variables input suppliers	$\Delta PS_{X_{nv}} = w_{nv}^{(1)} X_{nv}^{(1)} (E w_{nv} - t_{X_{nv}}) (1 + 0.5 E X_{nv})$
Farm non-variable input suppliers	$\Delta PS_{X_{no}} = w_{no}^{(1)} X_{no}^{(1)} (E w_{no} - t_{X_{no}}) (1 + 0.5 E X_{no})$
Wheat up-country storage other input suppliers	$\Delta PS_{Y_{n1o}} = v_{n1o}^{(1)} Y_{n1o}^{(1)} (E v_{n1o} - t_{Y_{n1o}}) (1 + 0.5 E Y_{n1o})$
Barley up-country storage other input suppliers	$\Delta PS_{Y_{n2o}} = v_{n2o}^{(1)} Y_{n2o}^{(1)} (E v_{n2o} - t_{Y_{n2o}}) (1 + 0.5 E Y_{n2o})$
Canola up-country storage other input suppliers	$\Delta PS_{Y_{n3o}} = v_{n3o}^{(1)} Y_{n3o}^{(1)} (E v_{n3o} - t_{Y_{n3o}}) (1 + 0.5 E Y_{n3o})$
Chickpeas up-country storage other input suppliers	$\Delta PS_{Y_{n4o}} = v_{n4o}^{(1)} Y_{n4o}^{(1)} (E v_{n4o} - t_{Y_{n4o}}) (1 + 0.5 E Y_{n4o})$
Milling other input suppliers	$\Delta PS_{F_{no}} = g_{no}^{(1)} F_{no}^{(1)} (E g_{no} - t_{F_{no}}) (1 + 0.5 E F_{no})$
Stockfeed manufacturing other input suppliers	$\Delta PS_{S_{no}} = t_{no}^{(1)} S_{no}^{(1)} (E t_{no} - t_{S_{no}}) (1 + 0.5 E S_{no})$
Malt manufacturing other input suppliers	$\Delta PS_{M_{no}} = n_{no}^{(1)} M_{no}^{(1)} (E n_{no} - t_{M_{no}}) (1 + 0.5 E M_{no})$
Oilseed crushing and refining	$\Delta PS_{C_{no}} = d_{no}^{(1)} C_{no}^{(1)} (E d_{no} - t_{C_{no}}) (1 + 0.5 E C_{no})$
<u>Southern Region Consumer Surplus Changes</u>	
Southern region grain storage and handlers of wheat	$\Delta CS_{Z_{n11}} = u_{n1}^{(1)} Z_{n11}^{(1)} (n_{Z_{n11}} - E u_{n11}) (1 + 0.5 E Z_{n11})$
Southern region grain storage and handlers of barley	$\Delta CS_{Z_{n12}} = u_{n12}^{(1)} Z_{n12}^{(1)} (n_{Z_{n12}} - E u_{n12}) (1 + 0.5 E Z_{n12})$
Southern region grain storage and handlers of canola	$\Delta CS_{Z_{n13}} = u_{n13}^{(1)} Z_{n13}^{(1)} (n_{Z_{n13}} - E u_{n13}) (1 + 0.5 E Z_{n13})$
<u>Export Consumer Surplus Changes</u>	
Export wheat consumers	$\Delta CS_{Z_{n1}} = u_{n1}^{(1)} Z_{n1}^{(1)} (n_{Z_{n1}} - E u_{n1}) (1 + 0.5 E Z_{n1})$
Export barley consumers	$\Delta CS_{Z_{n2}} = u_{n2}^{(1)} Z_{n2}^{(1)} (n_{Z_{n2}} - E u_{n2}) (1 + 0.5 E Z_{n2})$

Export canola consumers	$\Delta CS_{Zn3} = u_{n3}^{(1)} Z_{n3}^{(1)} (n_{Zn3} - E u_{n3}) (1 + 0.5 E Z_{n3})$
Export lupin consumers	$\Delta CS_{Zn4} = u_{n4}^{(1)} Z_{n4}^{(1)} (n_{Zn4} - E u_{n4}) (1 + 0.5 E Z_{n4})$
Export stockfeed consumers	$\Delta CS_{Sn1} = t_{n1}^{(1)} S_{n1}^{(1)} (n_{Sn1} - E t_{n1}) (1 + 0.5 E S_{n1})$
Export malt consumers	$\Delta CS_{Mn1} = n_{n1}^{(1)} M_{n1}^{(1)} (n_{Mn1} - E n_{n1}) (1 + 0.5 E M_{n1})$
Export canola oil consumers	$\Delta CS_{Cn1} = d_{n1}^{(1)} C_{n1}^{(1)} (n_{Cn1} - E d_{n1}) (1 + 0.5 E C_{n1})$

Domestic Consumer Surplus Changes

Domestic flour consumers	$\Delta CS_{Fn1} = g_{n1}^{(1)} F_{n1}^{(1)} (n_{Fn1} - E g_{n1}) (1 + 0.5 E F_{n1})$
Domestic stockfeed consumers	$\Delta CS_{Sn2} = t_{n2}^{(1)} S_{n2}^{(1)} (n_{Sn2} - E t_{n2}) (1 + 0.5 E S_{n2})$
Domestic malt consumers	$\Delta CS_{Mn2} = n_{n2}^{(1)} M_{n2}^{(1)} (n_{Mn2} - E n_{n2}) (1 + 0.5 E M_{n2})$
Domestic canola oil consumers	$\Delta CS_{Cn2} = d_{n2}^{(1)} C_{n2}^{(1)} (n_{Cn2} - E d_{n2}) (1 + 0.5 E C_{n2})$

Table 6.7 Total surplus change formulas for all 8 scenarios

<u>Scenario 1</u>	
Western Region ($t_{X_{WV}} = -1\%$)	$\Delta TS = -w_{WV}^{(1)} X_{WV}^{(1)} t_{X_{WV}} (1 + 0.5EX_{WV})$
Southern Region ($t_{X_{SV}} = -1\%$)	$\Delta TS = -w_{SV}^{(1)} X_{SV}^{(1)} t_{X_{SV}} (1 + 0.5EX_{SV})$
Northern Region ($t_{X_{NV}} = -1\%$)	$\Delta TS = -w_{NV}^{(1)} X_{NV}^{(1)} t_{X_{NV}} (1 + 0.5EX_{NV})$
<u>Scenario 2</u>	
Western Region ($t_{Y_{W10}} = -1\%$)	$\Delta TS = -v_{W10}^{(1)} Y_{W10}^{(1)} t_{Y_{W10}} (1 + 0.5EY_{W10})$
Southern Region ($t_{Y_{S10}} = -1\%$)	$\Delta TS = -v_{S10}^{(1)} Y_{S10}^{(1)} t_{Y_{S10}} (1 + 0.5EY_{S10})$
Northern Region ($t_{Y_{N10}} = -1\%$)	$\Delta TS = -v_{N10}^{(1)} Y_{N10}^{(1)} t_{Y_{N10}} (1 + 0.5EY_{N10})$
<u>Scenario 3</u>	
Western Region ($t_{F_{W0}} = -1\%$)	$\Delta TS = -g_{W0}^{(1)} F_{W0}^{(1)} t_{F_{W0}} (1 + 0.5EF_{W0})$
Southern Region ($t_{F_{S0}} = -1\%$)	$\Delta TS = -g_{S0}^{(1)} F_{S0}^{(1)} t_{F_{S0}} (1 + 0.5EF_{W0})$
Northern Region ($t_{F_{N0}} = -1\%$)	$\Delta TS = -g_{S0}^{(1)} F_{S0}^{(1)} t_{F_{S0}} (1 + 0.5EF_{W0})$
<u>Scenario 4</u>	
Western Region ($t_{S_{W0}} = -1\%$)	$\Delta TS = -t_{W0}^{(1)} S_{W0}^{(1)} t_{S_{W0}} (1 + 0.5ES_{W0})$
Southern Region ($t_{S_{S0}} = -1\%$)	$\Delta TS = -t_{S0}^{(1)} S_{S0}^{(1)} t_{S_{S0}} (1 + 0.5ES_{S0})$
Northern Region ($t_{S_{N0}} = -1\%$)	$\Delta TS = -t_{N0}^{(1)} S_{N0}^{(1)} t_{S_{N0}} (1 + 0.5ES_{N0})$
<u>Scenario 5</u>	
Western Region ($n_{S_{W1}} = -1\%$)	$\Delta TS = t_{W1}^{(1)} S_{W1}^{(1)} n_{S_{W1}} (1 + 0.5ES_{W1})$
Southern Region ($n_{S_{S1}} = -1\%$)	$\Delta TS = t_{S1}^{(1)} S_{S1}^{(1)} n_{F_{S1}} (1 + 0.5ES_{S1})$
Northern Region ($n_{S_{N1}} = -1\%$)	$\Delta TS = t_{N1}^{(1)} F_{N1}^{(1)} n_{F_{N1}} (1 + 0.5ES_{N1})$
<u>Scenario 6</u>	

<i>Western Region</i> ($n_{Sw2} = -1\%$)	$\Delta TS = t_{w2}^{(1)} S_{w2}^{(1)} n_{Sw2} (1 + 0.5ES_{w2})$
<i>Southern Region</i> ($n_{Ss2} = -1\%$)	$\Delta TS = t_{s2}^{(1)} S_{s2}^{(1)} n_{Ss2} (1 + 0.5ES_{s2})$
<i>Northern Region</i> ($n_{Sn2} = -1\%$)	$\Delta TS = t_{n2}^{(1)} F_{n2}^{(1)} n_{Sn2} (1 + 0.5ES_{n2})$
<u>Scenario 7</u>	
<i>Western Region</i> ($n_{Zw1} = -1\%$)	$\Delta TS = u_{w1}^{(1)} Z_{w1}^{(1)} n_{Zw1} (1 + 0.5EZ_{w1})$
<i>Southern Region</i> ($n_{Zs1} = -1\%$)	$\Delta TS = u_{s1}^{(1)} Z_{s1}^{(1)} n_{Zs1} (1 + 0.5EZ_{s1})$
<i>Northern Region</i> ($n_{Zn1} = -1\%$)	$\Delta TS = u_{n1}^{(1)} Z_{n1}^{(1)} n_{Zn1} (1 + 0.5EZ_{n1})$
<u>Scenario 8</u>	
<i>Western Region</i> ($n_{Zw2} = -1\%$)	$\Delta TS = u_{w2}^{(1)} Z_{w2}^{(1)} n_{Zw2} (1 + 0.5EZ_{w2})$
<i>Southern Region</i> ($n_{Zs2} = -1\%$)	$\Delta TS = u_{s2}^{(1)} Z_{s2}^{(1)} n_{Zs2} (1 + 0.5EZ_{s2})$
<i>Northern Region</i> ($n_{Zn2} = -1\%$)	$\Delta TS = u_{n2}^{(1)} Z_{n2}^{(1)} n_{Zn2} (1 + 0.5EZ_{n2})$

6.6 Summary

In this chapter, input data consisting of the base prices and quantities and market parameters, along with the exogenous shifter variables are defined.

The base prices and quantities for the various industry markets in each region are specified based on data presented in Chapters 3 and 4 and are derived from a number of sources including Australian Crop Forecasters, ABARES, AEGIC, JCS Solutions, IBISWorld, industry experts, along with some subjective judgements. In most instances, values were specified as the mean prices and quantities reported by the Australian Crop Forecasters and ABARES between the five year interval of 2011-12 to 2015-16.

A review of relevant empirical estimates of market elasticities was provided. Where applicable, the elasticity values specified in Tables 6.5, 6.6 and 6.7 were based on these published estimates.

However, due to a dearth of published estimates for the Australian grains industry, a level of subjective judgement was also necessary.

For each investment scenario, a small 1% shift to the relevant demand and supply curves is imposed to the exogenous shifter variables as specified in Table 6.8.

Having calibrated the model with these input data values, the EDMs outlined in Chapter 5 can then be run to obtain the resulting displacements in prices and quantities, along with the corresponding economic and welfare implications, all of which are reported and presented in the next Chapter.

Chapter 7 Results from the Base Models

7.1 Introduction

Using the data and parameters specified in Chapter 6, the equations for the EDM are solved to obtain changes to prices and quantities for a total of eight policy scenarios. For each scenario an exogenous demand or supply shock occurs in a market followed by endogenous changes in response to the shock occurring in other markets of the model. Consequently, prices and quantities in all markets change. In this chapter, the percentage changes in prices and quantities for each scenario in all sectors are reported for each of the three regions. The changes in prices and quantities are used to estimate the economic welfare implications, including the distribution of economic benefits for the different markets within each region.

The resulting total economics surplus changes and distributional impacts among all the various industry groups in all three regions are presented in Tables 7.1 to 7.6. In each scenario, the shifts considered are small parallel shifts, allowing for good approximations of price and quantity changes. To provide an understanding of the differences in impact that different investment scenarios can have, a detailed analysis and discussion of three key scenarios (Scenarios 1, 4 and 7) for each region are provided in Section 7.2. In each of these scenarios, a different segment in the supply chain is targeted for RD&E, with Scenario 1 targeting upstream production, Scenario 4 targeting intermediate processing, and Scenario 7 targeting end consumers. An overarching comparison of all scenarios and their policy implications is discussed in the following chapter. Section 7.3 presents the complete summary results for each region.

As explained by Alston (1995), for any market level, the producer surplus is the sum of quasi-rents accruing to all factors used in the production of the output(s) in the market (i.e. factors used up to that market level). The consumer surplus at that market level is the sum of final consumer surplus and the quasi-rents accruing to all factors used in conjunction with the produced good (i.e. beyond the current market level).

7.2 Analysis of Selected Scenarios under Each Region

Scenario 1: Farm Production Research

Scenario 1 considers new technologies or practices adopted from RD&E that either reduce the variable costs of farm production or increases the productivity of these inputs. This is modelled as a 1% downward shift of the supply curve of these variable inputs to the farm sector. Variable inputs consist of raw materials such as seed, fertiliser, fuel, water, and chemicals, along with other materials and services.

Western Region

In the Western Region, the 1 per cent reduction in variable farm cost is represented as a downward shift of the supply curve for variable farm inputs ($t_{xwv} = -0.01$). The changes in demand and supply, shown as shifts in supply and demand curves across all markets, are depicted in Figure 7.1 (not to scale).

This downwards shift in supply for variable farm inputs results in higher quantities and lower prices of these inputs. The reduction in costs of these inputs causes a downward shift of the supply curves of these outputs ($Y_{w1}, Y_{w2}, Y_{w3}, Y_{w4}$), increasing quantities and reducing prices of these outputs. The reduced cost in grain production causes the supply curves of outputs in all downstream markets

($Z_{w1}, Z_{w2}, Z_{w3}, Z_{w4}, Z_{w5}, Z_{w6}, Z_{w7}, Z_{w8}, Z_{w9}, Z_{w10}, F_{w1}, F_{w2}, S_{w1}, S_{w2}, M_{w1}, M_{w2}, C_{w1}, C_{w2}, C_{w3}$) , to also shift downwards, causing prices to decrease and quantities to increase for all these outputs.

On the demand side, a reduction in 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 the storage sector ($Y_{w1}, Y_{w2}, Y_{w3}, Y_{w4}$), as well as grain outputs from the storage market going into the secondary processing markets ($Z_{w5}, Z_{w6}, Z_{w7}, Z_{w8}, Z_{w9}, Z_{w10}$) to shift upwards to the right. The demand curves for millmix (F_{w2}) and canola meal (C_{w1}) going into stockfeed manufacturing also shift for these reasons. In addition, second round shifts in input demand and output supply also take effect due to substitution effects. Figure 7.1 illustrates the end results of all these shifts. On balance, the downwards supply shifts for these dominate for the majority of these grain and grain products because the base

results show that the prices for these grains decrease. The only instance where the upwards shift in demand dominates is for millmix (F_{w2}), where both its prices and quantities increase.

The supply curves of other inputs in all markets (X_{wo} , Y_{1wo} , Y_{2wo} , Y_{3wo} , Y_{4wo} , F_{wo} , S_{wo} , M_{wo} , C_{wo}) 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.

These displacements cause the total surplus gain for the industry to be an estimated \$24.22 million per year. All industry groups experience gains in welfare. The farm sector is the main beneficiary of the technology shock with a producer surplus of \$14.40 million being 59.4 per cent of the total surplus gain. The bulk storage and handling market receives \$2.11 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 \$6.52 million or 26.9 per cent of the total benefits.

These results are largely consistent with theory and with findings from previous studies. Alston *et al.* (2004) point out that for export-oriented agricultural industries operating in markets where prices are determined internationally (high export demand elasticity), the larger share of the benefits from research will be retained by the innovating industry and the factors of production it uses. This logic was supported by the Productivity Commission (2011), which inquired into the benefits of investments by rural R&D corporations. It reported that ‘while some of the research has contributed to better environmental and social outcomes, most of the reported benefits have taken the form of saving in producers’ inputs costs or other sources of productivity improvement, such as higher yields or more efficient farming practices’.

Southern Region

The impacts of the exogenous 1 per cent reduction in variable farm costs ($t_{xsv} = -0.01$) are similar for the southern region.

The downwards shift in supply for variable farm inputs results in higher quantities and lower prices of these inputs. The reduction in costs of these inputs causes a downward shift of the supply curves of wheat, barley, canola and peas (Y_{s1} , Y_{s2} , Y_{s3} , Y_{s4}), increasing quantities and reducing prices of these

outputs. Outputs in all downstream markets are subsequently shifted downwards, decreasing their prices and quantities.

Consumption in both the domestic and overseas markets for grain and grain products increases due to the reduced costs of grain at farmgate. This causes all intermediate demand ($Y_{s1}, Y_{s2}, Y_{s3}, Y_{s4}, Z_{s5}, Z_{s6}, Z_{s7}, Z_{s8}, Z_{s9}, Z_{s10}, F_{s2}, C_{s1}$) to increase. On balance, the downwards supply shifts dominate for all of these grain and grain products aside from millmix (F_{s2}).

The supply curves of other inputs in all markets ($X_{so}, Y_{1so}, Y_{2so}, Y_{3so}, Y_{4so}, F_{so}, S_{so}, M_{so}, C_{so}$) 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_{s5}), barley (Y_{s6}) and canola (Y_{s7}) from other regions also remain fixed as they are exogenous inputs to the southern region EDM. Instead, their demand curves have shifted marginally 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 \$18.52 million per year, smaller than the western region due to the lower gross revenue at farm gate of \$2,787 million per year compared to the \$3,642 million per year in the case of the western region. All industry groups experience gains in welfare. The farm sector is the main beneficiary of the technology shock with a total producer surplus of \$9 million, translating to 48.6 per cent of the total surplus gain. The bulk storage and handling market obtains \$1.60 million or 8.6 per cent of the total benefits. The total benefit accruing to all overseas consumers is \$4.27 million or 23 per cent of the total benefits. Compared to the western region, domestic consumers in the southern region gain a much larger share of total benefits at 13.4 per cent (2.47 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.

Northern Region

An exogenous 1 per cent reduction in variable farm costs ($t_{xnv} = -0.01$) is represented by a downwards shift in the supply curve for variable farm inputs, resulting in higher quantities and lower prices of these inputs. The reduction in costs of these inputs causes a downward shift of the supply curves of wheat, barley, canola and chickpeas ($Y_{n1}, Y_{n2}, Y_{n3}, Y_{n4}$), increasing quantities and reducing

prices of these outputs. Output supplies in all downstream markets are subsequently shifted downwards, decreasing their prices and quantities.

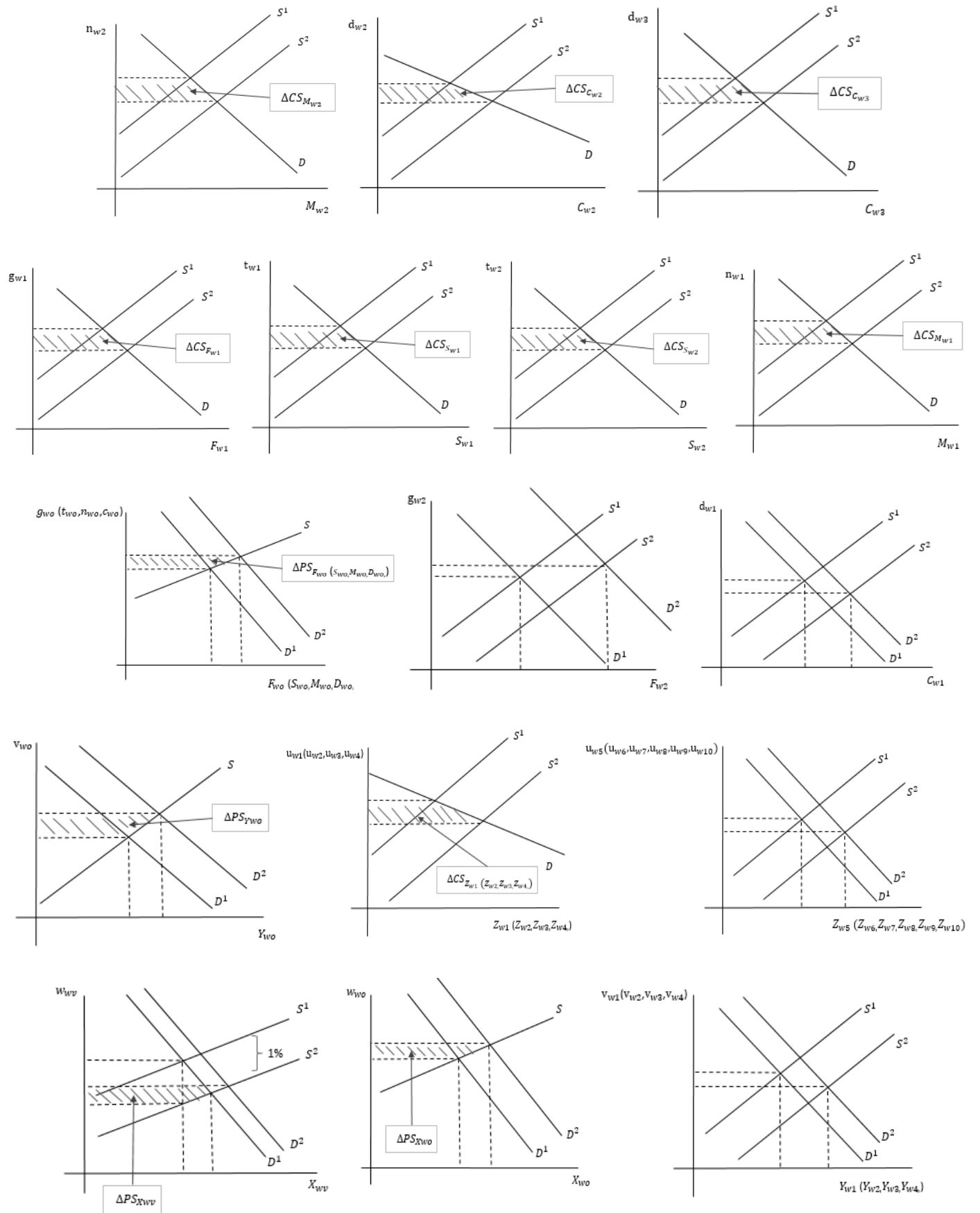
Consumption in both the domestic and overseas markets for grain and grain products increases due to the reduced costs of grain at farmgate. This causes all intermediate demand ($Y_{n1}, Y_{n2}, Y_{n3}, Y_{n4}, Z_{n5}, Z_{n6}, Z_{n7}, Z_{n8}, Z_{n9}, Z_{n10}, F_{n2}, C_{n1}$) to increase. On balance, the downwards supply shifts dominate for the all of these grain and grain products.

The supply curves of other inputs in all markets ($X_{no}, Y_{1no}, Y_{2no}, Y_{3no}, Y_{4no}, F_{no}, S_{no}, M_{no}, C_{no}$) 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 inter-regional demand curves of wheat (Z_{n11}), barley (Z_{n12}) and canola (Z_{n13}) remain fixed as they are exogenous inputs to the northern region EDM. Instead, their supply curves shift downwards.

These displacements cause the total surplus gain for the industry to be an estimated \$19.87 million per year, smaller than the western region but larger than the southern region. This is due to the gross revenue at farm gate of \$3,002 million per year compared to the \$3,642 million per year in the case of the western region and \$2,787 million per year for the southern region. All industry groups experience gains in welfare. Again, the farm sector is the main beneficiary of the technology shock with a total producer surplus of \$7.88 million, or 39.7 per cent of the total surplus gain. The bulk storage and handling market obtains \$0.81 million or 4.1 per cent of the total benefits. Due to an increased supply of grains to the southern region, consumers there receive \$1.82 million or 9.2 per cent of the total surplus gain.

The total benefit accruing to all overseas consumers is \$3.22 million or 16.2 per cent of the total benefits. This is much lower compared with the western and southern regions due to a much smaller volume of grains flowing to the overseas markets. A large proportion of grains is used domestically with domestic consumers obtaining 23.8% (\$4.73 million) of total annual benefits. A significant proportion of benefit is acquired by states in the southern region whose consumers gain 9.2% or \$1,818 million of total annual benefits.

Figure 7.1. Market displacement and surplus changes in Scenario 1 for the western region ($t_{XWV} = -0.01$)

Scenario 4: New Processing Technology in Stockfeed Manufacturing

Scenario 4 considers new processing technologies or practices adopted from RD&E that either reduce the costs of stockfeed manufacturing or increases its productivity. This is modelled as a 1% downward shift of the supply curve of non-grain inputs to the stockfeed manufacturing market.

Western Region

New processing technology in the stockfeed manufacturing market is modelled as a 1% downward shift in the supply curve of other stockfeed inputs ($t_{sw0} = -1\%$).

The cost reduction in the other stockfeed manufacturing inputs reduces the costs of final stockfeed destined for both the export (S_{w1}) and domestic (S_{w2}) markets, shifting the supply curves of these products downwards, reducing their prices and quantities.

The increased volume of final stockfeed demand results in upward shifts in the derived input demand for feed wheat (Z_{w6}), barley (Z_{w7}) and lupins (Z_{w10}), and consequently the derived input demand for wheat (Y_{w1}), barley (Y_{w2}) and lupins (Y_{w4}) at the farmgate along with their input demand curves for farm inputs (X_{w0} , Y_{w0}). This causes downward shifts in the supply curves of these grains, partially offsetting the initial upward demand shifts.

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_{w1}), malt manufacturing (M_{w1} , M_{w2}) and oilseed and crushing (C_{w2} , C_{w3}) markets. A downwards supply shift is also a dominant effect for export wheat (Z_{w1}). On the other hand, upwards supply shifts are the dominant effect for export barley (Z_{w2}), canola (Z_{w3}) and lupins (Z_{w4}).

The gross annual benefits are small due to the minor size of the stockfeed manufacturing in the western region. The estimated total surplus gain is around \$0.92 million per year. The share of benefits is largest for domestic consumers of stockfeed at 37.5% (\$0.35 milion). This is primarily due to the assumption of inelastic domestic demand for stockfeed ($\eta_{sw2,tw2} = -0.5$). In contrast, the share of benefits flowing to overseas consumers is 7.1% (\$0.07 million) as a very high export demand elasticity for stockfeed is assumed

($\eta_{Sw1,tw1} = -4.0$). The stockfeed manufacturing market also gains a large share of total annual benefits at 22.9% (\$0.21 million). This is largely due to the assumed moderate value of the elasticity of supply of other inputs in the stockfeed manufacturing market ($\varepsilon_{Sw0,tw0} = 1.0$). The farm sector only receives 18.5% (\$0.17 million) of the total benefits as most of the benefits are already absorbed by the stockfeed manufacturing market and domestic consumers for stockfeed.

Southern Region

The results for a 1% downward shift in the supply curve of other stockfeed inputs in the southern region ($t_{Ss0} = -1\%$) are shown in Table 7.4. The estimated total surplus gain is around \$4.00 million per year. This is larger compared to the western region as the stockfeed manufacturing industry is more significant in the southern region in gross value terms. The share of benefits is largest for domestic consumers of stockfeed at 37.1% (\$1.48 million). Again, this is due to the assumption of inelastic domestic demand for stockfeed ($\eta_{Ss2,ts2} = -0.5$). In contrast, the share of benefits flowing to overseas consumers is 9.6% (\$0.38 million) as a very high export demand elasticity for stockfeed is assumed ($\eta_{Ss1,ts1} = -4.0$). Similarly, the stockfeed manufacturing industry also gains a large share of total annual benefits at 24.3% (\$0.97 million). A smaller share is received by the farm sector at 14.3% (\$0.57 million) of the total benefits. In addition, a small share of benefits (3.4%) flows to the northern region.

Northern Region

The results for a 1% downward shift in the supply curve of other stockfeed inputs in the northern region ($t_{Sn0} = -1\%$) are shown in Table 7.6. The estimated total surplus gain is around \$4.87 million per year due to the larger size of the stockfeed industry in the northern region in gross value terms compared to western and southern regions. Here, domestic consumers of stockfeed gain 34.9% (\$1.70 million) whereas overseas consumers gain 8.5% (\$0.42 million). The stockfeed manufacturing industry also gains a significant share of total annual benefits at 22.5% (\$1.10 million). The farm production sector gains 15.7% (\$0.76 million) of the total benefits. In addition, a small share of benefits (1.3%) flows to the southern region.

Scenario 7: Export Promotion or Quality Improving Research for Export Wheat

Scenario 7 models the effects of a 1% increase in overseas consumers' willingness to pay for wheat. This can arise through promotion investment or an improvement of the quality of wheat through RD&E, and is modelled as an upward shift of the demand curve of wheat sold in the export market.

Western Region

For the Western Region, the exogenous shock examined is a 1 per cent upward shift of the demand curve for export wheat ($t_{Zw1} = 0.01$). This can be the result of quality enhancing research which increases the willingness to pay by overseas consumers or through investments in advertising, education and promotion in overseas markets.

The upward shift of the demand of export wheat increases both its quantity (Z_{w1}) and price (u_{w1}). Due to the increase in export demand for wheat, the derived input demand curves for grain input going into the wheat storage sector (Y_{w1}) are shifted upwards along with the input demand curves for farm inputs (X_{wo}, X_{wv}). The higher farm gate price of wheat triggers a decrease in production supply of the other grains (Y_{w2}, Y_{w3}, Y_{w4}), facilitated by the high elasticity of output transformation between wheat and other grains at the farm level. This will also result in upward shifts in their supply curves (decreasing supply) of these grain inputs going into storage resulting in decreases in their quantities and increases in their prices as shown in Table 7.1. This subsequently causes a reduction in the supply for the majority of outputs coming from the storage of these grains ($Z_{w2}, Z_{w3}, Z_{w4}, Z_{w7}, Z_{w8}, Z_{w9}$).

As the aggregate input index of the wheat storage sector (EY^{ww}) has now increased, this then results in increases (downward shifts) in the supply for export wheat (Z_{w1}), partially offsetting the initial upwards shift in its demand. The output supply of feed wheat (Z_{w6}) increases and subsequently causes the supply of outputs in the stockfeed manufacturing sector (S_{w1}, S_{w2}) to also increase. The supply of barley and lupins destined for stockfeed manufacturing (Z_{w7}, Z_{w10}) increase due to their substitutability for stockfeed wheat. The output supply of wheat going into milling (Z_{w5}) however, decreases due to its high level of output substitution with export wheat ($\tau_{Zw1, Zw5} = -3.0$). This decrease in supply for milling wheat also slightly decreases the supply of flour (F_{w1}) and millmix (F_{w2}) in the final domestic market and stockfeed manufacturing sector respectively.

The supply curves of other inputs in all sectors remain stationary as they are exogenous inputs to the model. The demands curves for X_{wo} , X_{wv} , Y_{w10} and S_{wo} shift upwards because of the increase in

export demand for wheat as well as an increase in supply for stockfeed. On the other hand, the demands curves for Y_{2wo} , Y_{3wo} , Y_{4wo} , F_{wo} , S_{wo} , M_{wo} , C_{wo} all shift downwards.

The large gross revenue of the export wheat market for WA means the estimated total surplus gain from this hypothetical scenario is \$26.07 million per year. The economic benefit to the farm sector is \$16.01 million or 61.4 per cent of the total benefits. The other major beneficiaries in this scenario include bulk storage (\$2.49 million) and overseas wheat consumers (\$7.83 million). Small losses in surplus also occur for various industry groups in the industry due to output transformation possibilities.

Southern Region

The upward shift of the demand curve of export wheat increases both its quantity (Z_{s1}) and prices (u_{s1}). The increase in export demand for wheat causes the derived input demand curves for grain input going into the wheat storage sector (Y_{s1}) to be shifted upwards along with the input demand curves for farm inputs (X_{so} , X_{sv}). The higher farm gate price of wheat triggers a decrease in production supply of the other grains (Y_{s2} , Y_{ws3} , Y_{s4}), facilitated by the high elasticity of output transformation between wheat and other grains at farm production. This subsequently causes a reduction in the supply for the majority of outputs coming from the storage of these grains.

As the aggregate input index of the storage market (EY^{ss}) has now increased, this then results in increases (downward shifts) in the supply for the majority of outputs of the storage market (Z_{s1} , Z_{s2} , Z_{s3} , Z_{s4} , Z_{s6} , Z_{s7} , Z_{s8} , Z_{s9} , Z_{s10}). The output supply of wheat going into milling (Z_{s5}) however, decreases due to its high level of output substitution with export wheat ($\tau_{Zs1,Zs5} = -3.0$). Similarly, the supply of outputs in the stockfeed (S_{s1} , S_{s2}), malting (M_{s1} , M_{s2}), and oilseed crushing and refining (C_{s1} , C_{s2} , C_{s3}) markets also increase (shift downwards). The consumption for final processed products in these markets increase, causing additional outward shifts in demand for inputs going into these three markets (Z_{s6} , Z_{s7} , Z_{s8} , Z_{s9} , Z_{s10}). However, these demand shifts are dominated by the downward supply shifts as shown by the increases in quantities and decreases in prices in Table 7.2. On the other hand, the decrease in supply for milling wheat, also slightly decreases the supply of flour (F_{s1}) and millmix (F_{s2}) in the final domestic market and stockfeed manufacturing market respectively.

The supply curves of other inputs in all markets remain stationary as they are exogenous inputs to the model. The demands curves for X_{so} , Y_{s1o} , S_{so} , M_{so} , C_{so} shift outwards because of increases in final

consumption of grain and grain products in these markets. The demand curve for F_{so} however, shifts backwards due to a slight reduction in the final consumption of flour.

The supply curves of wheat (Y_{s5}), barley (Y_{s6}) and canola (Y_{s7}) remain exogenous, whereas their demand curves shift due to increases in final consumption of grain and grain products.

The estimated total surplus gain in the southern region is \$18.87 million per year. This is smaller than the western region 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 \$8.89 million or 47.1% of total benefits, due to the high export demand elasticity for wheat. A significant share of total benefits is also received by the northern region at \$2.55 million or 13.5% of total benefits. The other major beneficiaries in this scenario include bulk storage (\$1.80 million per annum; 9.6% of share), overseas wheat consumers (\$4.62 million; 24.3% of total benefits) and stockfeed manufacturing (\$1.15 million; 6.1% of total benefits). In total, overseas consumers gain 23.6 per cent of the total benefits whereas domestic consumers receive 4.2 per cent of total benefits.

Northern Region

A 1 per cent shift in the demand curve of export wheat in the northern region has similar displacement effects for the prices and quantities of the grain and grain products in each market compared to the western and southern regions.

The total surplus gain for the industry is estimated to be \$9.81 million per year, which is significantly smaller compared to both the western and southern regions. This is due to the smaller gross revenue of export wheat in the southern region at \$981 million per year compared to the \$2,593 million per year in the case of the western region and \$1,880 million per year for the southern region. The farm sector is the main beneficiary of the technology shock with a total producer surplus of \$5.93 million (60.5 per cent) of the total surplus gain. The bulk storage and handling market obtains \$0.75 million or 7.6 per cent of the total benefits. The increase in price and profitability of export wheat causes a reduction in supply of grains to the southern region due to an output substitution effect. As a result, southern region consumers experience a loss of \$0.19 million per year or 2.0 per cent of total benefits.

7.3 Summary of Results for Each Regional EDM

This section provides a summary of the simulations results obtained from the base models for each region. For each region, the final displacements in market prices and quantities are reported as percentage changes for each investment scenario. These resulting percentage changes in prices and quantities are then used to calculate the total economic surplus changes and the distribution of the surpluses among the various industry groups using the formulas provided in Tables 6.6 to 6.9.

7.3.1 Western Region

Table 7.1 Western region percentage changes in prices and quantities (%)

	Scenario 1 ($t_{Xwv} = -1\%$)	Scenario 2 ($t_{Yw10} = -1\%$)	Scenario 3 ($t_{Fw0} = -1\%$)	Scenario 4 ($t_{Sw0} = -1\%$)	Scenario 5 ($n_{Sw1} = 1\%$)	Scenario 6 ($n_{Sw2} = 1\%$)	Scenario 7 ($n_{Zw1} = 1\%$)	Scenario 8 ($n_{Zw2} = 1\%$)
Quantities:								
eX_{wv}	0.79	0.13	0.00	0.01	0.02	0.01	0.81	-0.18
eX_{w0}	0.65	0.13	0.00	0.01	0.02	0.01	0.77	-0.17
eY_{w1}	0.74	0.24	0.00	0.01	0.02	0.01	1.44	0.06
eY_{w2}	0.62	-0.03	0.00	0.01	0.01	0.01	-0.20	-1.52
eY_{w3}	0.85	-0.05	0.00	0.00	0.00	0.00	-0.28	0.06
eY_{w4}	0.64	-0.03	0.00	0.05	0.11	0.07	-0.18	0.05
eY_{w10}	0.69	0.33	0.00	0.01	0.02	0.01	1.45	0.05
eY_{w20}	0.57	-0.03	0.00	0.01	0.01	0.01	-0.18	-1.51
eY_{w30}	0.79	-0.04	0.00	0.00	0.00	0.00	-0.26	0.06
eY_{w40}	0.58	-0.02	0.00	0.05	0.11	0.07	-0.16	0.04
eZ_{w1}	0.76	0.26	0.00	0.01	0.01	0.01	1.50	0.06
eZ_{w2}	0.66	-0.04	0.00	0.00	0.00	0.00	-0.22	-1.71

eZ_{w3}	0.86	-0.05	0.00	0.00	-0.01	0.00	-0.29	0.06
eZ_{w4}	0.81	-0.04	0.00	0.00	-0.01	-0.01	-0.27	0.06
eZ_{w5}	0.12	0.04	0.14	0.03	0.05	0.03	-0.04	0.01
eZ_{w6}	0.41	0.13	0.00	0.12	0.24	0.16	0.52	0.03
eZ_{w7}	0.24	0.01	0.01	0.17	0.34	0.23	0.03	-0.06
eZ_{w8}	0.24	-0.01	0.00	0.00	0.00	0.00	-0.08	-0.10
eZ_{w9}	0.31	-0.01	0.00	0.07	0.15	0.10	-0.06	0.02
eZ_{w10}	0.24	0.01	0.01	0.18	0.36	0.24	0.03	0.01
eF_{w0}	0.08	0.02	0.23	0.02	0.05	0.03	-0.02	0.01
eF_{w1}	0.10	0.03	0.18	0.02	0.05	0.03	-0.03	0.01
eF_{w2}	0.10	0.03	0.18	0.03	0.06	0.04	-0.03	0.01
eS_{w0}	0.23	0.05	0.01	0.23	0.28	0.19	0.17	0.00
eS_{w1}	0.54	0.12	0.03	0.32	1.07	-0.18	0.41	0.01
eS_{w2}	0.16	0.03	0.01	0.10	-0.08	0.35	0.12	0.00
eM_{w0}	0.19	-0.01	0.00	0.00	0.00	0.00	-0.06	-0.08
eM_{w1}	0.25	-0.01	0.00	0.00	0.00	0.00	-0.08	-0.11
eM_{w2}	0.07	0.00	0.00	0.00	0.00	0.00	-0.02	-0.03
eC_{w0}	0.25	0.00	0.00	0.07	0.14	0.09	-0.04	0.02
eC_{w1}	0.30	0.00	0.00	0.07	0.15	0.10	-0.05	0.02
eC_{w2}	0.47	-0.01	0.00	0.11	0.22	0.15	-0.09	0.03
eC_{w3}	0.16	0.00	0.00	0.04	0.07	0.05	-0.03	0.01
Prices:								
ew_{wv}	-0.74	0.04	0.00	0.00	0.01	0.00	0.27	-0.06
ew_{w0}	0.65	0.13	0.00	0.01	0.02	0.01	0.77	-0.17
ev_{w1}	-0.27	0.11	0.00	0.01	0.01	0.01	0.65	-0.02
ev_{w2}	-0.31	0.02	0.00	0.00	0.01	0.01	0.10	-0.54
ev_{w3}	-0.23	0.01	0.00	0.00	0.00	0.00	0.08	-0.02
ev_{w4}	-0.30	0.02	0.00	0.02	0.04	0.03	0.11	-0.02

ev _{w10}	0.28	-0.87	0.00	0.00	0.01	0.01	0.58	0.02
ev _{w20}	0.23	-0.01	0.00	0.00	0.00	0.00	-0.07	-0.61
ev _{w30}	0.32	-0.02	0.00	0.00	0.00	0.00	-0.10	0.02
ev _{w40}	0.23	-0.01	0.00	0.02	0.04	0.03	-0.06	0.02
eu _{w1}	-0.15	-0.05	0.00	0.00	0.00	0.00	0.70	-0.01
eu _{w2}	-0.13	0.01	0.00	0.00	0.00	0.00	0.04	-0.66
eu _{w3}	-0.17	0.01	0.00	0.00	0.00	0.00	0.06	-0.01
eu _{w4}	-0.16	0.01	0.00	0.00	0.00	0.00	0.05	-0.01
eu _{w5}	-0.37	-0.13	0.05	0.01	0.01	0.01	0.18	-0.03
eu _{w6}	-0.83	-0.30	0.01	0.22	0.46	0.30	-1.21	-0.07
eu _{w7}	-0.34	0.03	0.00	0.09	0.18	0.12	0.17	0.17
eu _{w8}	-0.34	0.02	0.00	0.00	0.00	0.00	0.11	0.14
eu _{w9}	-0.36	0.02	0.00	0.03	0.05	0.03	0.13	-0.03
eu _{w10}	-0.35	0.03	0.00	0.06	0.13	0.08	0.15	-0.03
eg _{w0}	0.05	0.02	-0.85	0.02	0.03	0.02	-0.01	0.00
eg _{w1}	-0.20	-0.07	-0.36	-0.05	-0.10	-0.07	0.06	-0.01
eg _{w2}	0.03	-0.02	-0.48	0.47	0.97	0.64	0.32	-0.01
et _{w0}	0.23	0.05	0.01	-0.77	0.28	0.19	0.17	0.00
et _{w1}	-0.13	-0.03	-0.01	-0.08	0.73	0.04	-0.10	0.00
et _{w2}	-0.32	-0.07	-0.02	-0.19	0.16	0.31	-0.24	-0.01
en _{w0}	0.19	-0.01	0.00	0.00	0.00	0.00	-0.06	-0.08
en _{w1}	-0.06	0.00	0.00	0.00	0.00	0.00	0.02	0.03
en _{w2}	-0.15	0.01	0.00	0.00	0.00	0.00	0.05	0.06
ed _{w0}	0.25	0.00	0.00	0.07	0.14	0.09	-0.04	0.02
ed _{w1}	-0.53	0.08	0.01	0.35	0.71	0.47	0.39	-0.05
ed _{w2}	-0.12	0.00	0.00	-0.03	-0.06	-0.04	0.02	-0.01
ed _{w3}	-0.31	0.01	0.00	-0.07	-0.15	-0.10	0.06	-0.02

Table 7.2 Western Region economic surplus changes (\$ million) and percentage shares of total surplus changes (%) to various industry groups

	Scenario 1 ($t_{XWV} = -1\%$)		Scenario 2 ($t_{YW10} = -1\%$)		Scenario 3 ($t_{FW0} = -1\%$)		Scenario 4 ($t_{SW0} = -1\%$)		Scenario 5 ($n_{SW1} = 1\%$)		Scenario 6 ($n_{SW2} = 1\%$)		Scenario 7 ($n_{ZW1} = 1\%$)		Scenario 8 ($n_{ZW2} = 1\%$)	
	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%
ΔPS_{XW0}	8.02	33.1%	1.55	33.0%	0.02	3.7%	0.10	10.9%	0.21	25.5%	0.14	7.7%	9.43	36.2%	2.12	31.2%
ΔPS_{XWV}	6.38	26.3%	1.09	23.0%	0.01	2.6%	0.07	7.6%	0.14	17.8%	0.10	5.3%	6.58	25.2%	1.48	21.8%
Farm subtotal	14.40	59.4%	2.64	56.0%	0.03	6.3%	0.17	18.5%	0.35	43.3%	0.23	13.0%	16.01	61.4%	3.59	53.1%
ΔPS_{YW10}																
Bulk Storage for Wheat	1.31	5.4%	0.63	13.4%	0.01	1.0%	0.02	2.0%	0.04	4.6%	0.02	1.4%	2.74	10.5%	-0.10	-1.4%
ΔPS_{YW20}																
Bulk Storage for Barley	0.50	2.1%	-0.03	-0.6%	0.00	0.0%	0.01	0.6%	0.01	1.3%	0.01	0.4%	-0.16	-0.6%	1.33	19.6%
ΔPS_{YW30}																
Bulk Storage for Canola	0.25	1.0%	-0.01	-0.3%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	-0.08	-0.3%	-0.02	-0.3%
ΔPS_{YW40}																
Bulk Storage for Lupins	0.05	0.2%	0.00	0.0%	0.00	0.0%	0.00	0.5%	0.01	1.1%	0.01	0.3%	-0.01	-0.1%	0.00	-0.1%
Bulk Storage subtotal	2.11	8.7%	0.59	12.5%	0.01	1.0%	0.03	3.0%	0.06	7.1%	0.04	2.1%	2.49	9.5%	1.21	17.8%
ΔPS_{FW0}																
Flour Milling	0.03	0.1%	0.01	0.2%	0.08	15.1%	0.01	0.9%	0.02	2.1%	0.01	0.6%	-0.01	0.0%	0.00	0.0%
ΔPS_{SW0}																
Stockfeed manufacturing	0.21	0.9%	0.01	0.2%	0.01	2.4%	0.21	22.9%	0.26	32.4%	0.17	9.7%	0.16	0.6%	0.00	-0.1%

Chapter 7

Results from the Base Models

ΔPS_{Mwo} Malt Manufacturing	0.11	0.5%	-0.01	-0.1%	0.00	0.0%	0.00	0.1%	0.00	0.1%	0.00	0.0%	-0.04	-0.1%	0.05	0.7%
ΔPS_{Cwo} Canola Processing	0.01	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.3%	0.01	0.8%	0.00	0.2%	0.00	0.0%	0.00	0.0%
Producer Surplus subtotal:	16.87	69.6%	3.28	69.5%	0.13	24.8%	0.42	45.8%	0.69	85.9%	0.46	25.8%	18.61	71.4%	4.84	71.5%
Overseas Consumers:																
ΔCS_{Zw1} Export Wheat	3.95	16.3%	1.36	28.9%	0.00	-0.4%	0.03	3.5%	0.07	8.1%	0.04	2.4%	7.83	30.0%	-0.29	-4.3%
ΔCS_{Zw2} Export Barley	0.89	3.7%	-0.05	-1.0%	0.00	-0.1%	-0.00	-0.1%	0.00	-0.2%	0.00	-0.1%	-0.29	-1.1%	2.32	34.3%
ΔCS_{Zw3} Export Canola	1.34	5.5%	-0.07	-1.6%	0.00	-0.2%	-0.00	-0.5%	-0.01	-1.2%	-0.01	-0.4%	-0.44	-1.7%	-0.10	-1.5%
ΔCS_{Zw4} Export Lupins	0.16	0.6%	-0.01	-0.2%	0.00	0.0%	-0.00	-0.1%	0.00	-0.2%	0.00	-0.1%	-0.05	-0.2%	-0.01	-0.2%
ΔCS_{Sw1} Export Stockfeed	0.11	0.4%	0.02	0.5%	0.01	1.2%	0.07	7.1%	0.22	26.8%	-0.04	-2.0%	0.08	0.3%	0.00	0.0%
ΔCS_{Mw1} Export Malt	0.06	0.2%	0.00	-0.1%	0.00	0.0%	0.00	0.0%	0.00	0.1%	0.00	0.0%	-0.02	-0.1%	0.03	0.4%

ΔCS_{CW2} Export Canola Oil	0.02	0.1%	0.00	0.0%	0.00	0.0%	0.00	0.4%	0.01	1.0%	0.01	0.3%	0.00	0.0%	0.00	0.0%
Overseas consumers subtotal	6.52	26.9%	1.25	26.6%	0.00	0.6%	0.09	10.3%	0.28	34.3%	0.00	0.3%	7.10	27.2%	1.94	28.7%
Domestic Consumers:																
ΔCS_{FW1} Domestic Flour	0.20	0.8%	0.06	1.4%	0.35	68.1%	0.05	5.2%	0.10	12.1%	0.06	3.6%	-0.06	-0.2%	-0.01	-0.2%
ΔCS_{SW2} Domestic Stockfeed	0.57	2.4%	0.12	2.6%	0.03	6.5%	0.35	37.5%	-0.28	-35.1%	1.23	69.5%	0.43	1.7%	-0.01	-0.2%
ΔCS_{MW2} Domestic Malt	0.03	0.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	-0.01	0.0%	0.01	0.2%
ΔCS_{CW3} Domestic Canola Oil	0.05	0.2%	0.00	0.0%	0.00	0.1%	0.01	1.2%	0.02	2.7%	0.01	0.8%	-0.01	0.0%	0.00	0.0%
Domestic consumers subtotal	0.85	3.5%	0.19	3.9%	0.39	74.7%	0.40	43.9%	-0.16	-20.2%	1.31	73.9%	0.36	1.4%	-0.01	-0.2%
Consumer Surplus Subtotal	7.36	30.4%	1.44	30.5%	0.39	75.2%	0.50	54.2%	0.11	14.1%	1.32	74.2%	7.46	28.6%	1.93	28.5%
Total Economic Surplus	24.23	100.0%	4.72	100.0%	0.52	100.0%	0.92	100.0%	0.81	100.0%	1.78	100.0%	26.07	100.0%	6.77	100.0%

7.3.2 Southern Region

Table 7.3 Southern region percentage changes in prices and quantities (%)

	Scenario 1 ($t_{Xsv} = -1\%$)	Scenario 2 ($t_{Ys10} = -1\%$)	Scenario 3 ($t_{Fso} = -1\%$)	Scenario 4 ($t_{Sso} = 1\%$)	Scenario 5 ($n_{Ss1} = 1\%$)	Scenario 6 ($n_{Ss2} = 1\%$)	Scenario 7 ($n_{Zs1} = 1\%$)	Scenario 8 ($n_{Zs2} = 1\%$)
Quantities:								
eX_{sv}	0.66	0.12	0.01	0.04	0.07	0.05	0.59	0.21
eX_{so}	0.53	0.11	0.01	0.04	0.07	0.04	0.56	0.20
eY_{s1}	0.61	0.22	0.01	0.04	0.08	0.05	1.11	-0.05
eY_{s2}	0.54	-0.02	0.00	0.04	0.08	0.05	-0.11	1.08
eY_{s3}	0.73	-0.03	0.00	0.01	0.02	0.01	-0.16	-0.06
eY_{s4}	0.48	-0.01	0.00	0.06	0.12	0.08	-0.09	-0.04
eY_{s10}	0.47	0.30	0.01	0.04	0.07	0.05	1.03	-0.04
eY_{s20}	0.45	-0.02	0.00	0.04	0.08	0.05	-0.09	1.04
eY_{s30}	0.56	-0.02	0.00	0.01	0.02	0.01	-0.12	-0.05
eY_{s40}	0.37	-0.01	0.00	0.06	0.10	0.07	-0.06	-0.03
eY_{s5}	0.01	0.09	0.00	0.02	0.03	0.02	0.45	0.00
eY_{s6}	0.00	0.00	0.00	0.02	0.04	0.02	0.01	0.42
eY_{s7}	0.04	0.00	0.00	0.01	0.01	0.01	-0.01	0.00
eZ_{s1}	0.58	0.26	0.00	0.02	0.05	0.03	1.22	-0.05
eZ_{s2}	0.63	-0.03	0.00	0.00	0.00	0.00	-0.14	1.55
eZ_{s3}	0.74	-0.03	0.00	-0.01	-0.03	-0.02	-0.17	-0.06
eZ_{s4}	0.69	-0.04	0.00	-0.04	-0.07	-0.05	-0.17	-0.06
eZ_{s5}	0.09	0.04	0.15	0.03	0.06	0.04	-0.07	-0.01
eZ_{s6}	0.30	0.12	0.01	0.14	0.26	0.17	0.34	-0.02
eZ_{s7}	0.20	0.01	0.01	0.18	0.34	0.22	0.02	0.02
eZ_{s8}	0.24	-0.01	0.00	0.01	0.02	0.01	-0.05	0.05
eZ_{s9}	0.25	0.00	0.00	0.08	0.14	0.09	-0.03	-0.02

eZ _{s10}	0.19	0.01	0.01	0.19	0.35	0.23	0.02	-0.01
eF _{so}	0.06	0.02	0.24	0.03	0.05	0.03	-0.04	0.00
eF _{s1}	0.07	0.03	0.19	0.03	0.05	0.04	-0.05	-0.01
eF _{s2}	0.08	0.03	0.19	0.03	0.06	0.04	-0.05	-0.01
eS _{so}	0.18	0.05	0.01	0.24	0.28	0.19	0.12	0.00
eS _{s1}	0.41	0.11	0.03	0.36	1.06	-0.18	0.28	-0.01
eS _{s2}	0.12	0.03	0.01	0.11	-0.08	0.35	0.08	0.00
eM _{so}	0.19	-0.01	0.00	0.01	0.01	0.01	-0.04	0.04
eM _{s1}	0.25	-0.01	0.00	0.01	0.02	0.01	-0.05	0.05
eM _{s2}	0.08	0.00	0.00	0.00	0.01	0.00	-0.02	0.01
eC _{so}	0.20	0.00	0.00	0.07	0.13	0.09	-0.02	-0.01
eC _{s1}	0.24	0.00	0.00	0.08	0.15	0.10	-0.03	-0.02
eC _{s2}	0.37	0.00	0.00	0.11	0.21	0.14	-0.04	-0.03
eC _{s3}	0.12	0.00	0.00	0.04	0.07	0.05	-0.01	-0.01
Prices:								
ew _{sv}	-0.78	0.04	0.00	0.01	0.02	0.02	0.20	0.07
ew _{so}	0.53	0.11	0.01	0.04	0.07	0.04	0.56	0.20
ev _{s1}	-0.34	0.10	0.00	0.02	0.04	0.03	0.50	0.03
ev _{s2}	-0.36	0.02	0.00	0.02	0.04	0.03	0.09	0.41
ev _{s3}	-0.30	0.01	0.00	0.01	0.02	0.01	0.07	0.03
ev _{s4}	-0.38	0.02	0.00	0.03	0.05	0.04	0.10	0.03
ev _{s10}	0.19	-0.88	0.00	0.02	0.03	0.02	0.41	-0.02
ev _{s20}	0.18	-0.01	0.00	0.02	0.03	0.02	-0.03	0.42
ev _{s30}	0.23	-0.01	0.00	0.00	0.01	0.01	-0.05	-0.02
ev _{s40}	0.74	-0.02	0.00	0.11	0.21	0.14	-0.13	-0.06
ev _{s5}	0.01	0.09	0.00	0.02	0.03	0.02	0.45	0.00
ev _{s6}	0.00	0.00	0.00	0.02	0.04	0.02	0.01	0.42
ev _{s7}	0.04	0.00	0.00	0.01	0.01	0.01	-0.01	0.00

eu _{s1}	-0.12	-0.05	0.00	0.00	-0.01	-0.01	0.76	0.01
eu _{s2}	-0.13	0.01	0.00	0.00	0.00	0.00	0.03	0.69
eu _{s3}	-0.15	0.01	0.00	0.00	0.01	0.00	0.03	0.01
eu _{s4}	-0.14	0.01	0.00	0.01	0.01	0.01	0.03	0.01
eu _{s5}	-0.30	-0.13	0.06	0.00	-0.01	0.00	0.28	0.02
eu _{s6}	-0.62	-0.29	0.00	0.22	0.41	0.27	-0.83	0.06
eu _{s7}	-0.34	0.03	0.00	0.10	0.19	0.12	0.11	-0.08
eu _{s8}	-0.32	0.01	0.00	-0.01	-0.02	-0.02	0.07	-0.06
eu _{s9}	-0.31	0.02	0.00	0.03	0.06	0.04	0.08	0.03
eu _{s10}	-0.31	0.02	0.00	0.08	0.15	0.10	0.10	0.03
eg _{s0}	0.04	0.02	-0.84	0.02	0.04	0.02	-0.02	0.00
eg _{s1}	-0.15	-0.06	-0.38	-0.06	-0.11	-0.07	0.10	0.01
eg _{s2}	0.03	-0.02	-0.54	0.53	0.98	0.65	0.31	0.01
et _{s0}	0.18	0.05	0.01	-0.76	0.28	0.19	0.12	0.00
et _{s1}	-0.10	-0.03	-0.01	-0.09	0.73	0.05	-0.07	0.00
et _{s2}	-0.25	-0.07	-0.02	-0.21	0.16	0.31	-0.17	0.00
en _{s0}	0.19	-0.01	0.00	0.01	0.01	0.01	-0.04	0.04
en _{s1}	-0.06	0.00	0.00	0.00	0.00	0.00	0.01	-0.01
en _{s2}	-0.15	0.01	0.00	-0.01	-0.01	-0.01	0.03	-0.03
ed _{s0}	0.20	0.00	0.00	0.07	0.13	0.09	-0.02	-0.01
ed _{s1}	-0.45	0.07	0.01	0.40	0.74	0.49	0.24	0.05
ed _{s2}	-0.09	0.00	0.00	-0.03	-0.05	-0.04	0.01	0.01
ed _{s3}	-0.25	0.00	0.00	-0.08	-0.14	-0.09	0.03	0.02

Table 7.4 Southern Region economic surplus changes (\$ million) and Percentage Shares of total surplus changes (%) to various industry groups

	Scenario 1 ($t_{Xsv} = -1\%$)		Scenario 2 ($t_{Ys1o} = -1\%$)		Scenario 3 ($t_{Fso} = -1\%$)		Scenario 4 ($t_{Sso} = -1\%$)		Scenario 5 ($n_{Ss1} = 1\%$)		Scenario 6 ($n_{Ss2} = 1\%$)		Scenario 7 ($n_{Zs1} = 1\%$)		Scenario 8 ($n_{Zs2} = 1\%$)	
	\$m	%					\$m	%					\$m	%		
ΔPS_{Xs0}	4.95	26.7%	1.06	22.5%	0.05	2.7%	0.34	8.4%	0.62	19.7%	0.41	5.9%	5.24	27.8%	1.89	30.1%
ΔPS_{Xsv}	4.05	21.9%	0.74	15.7%	0.03	1.9%	0.24	5.9%	0.44	13.8%	0.29	4.1%	3.66	19.4%	1.32	21.0%
Farm subtotal	9.00	48.6%	1.80	38.3%	0.08	4.6%	0.57	14.3%	1.06	33.5%	0.70	10.1%	8.89	47.1%	3.20	51.1%
ΔPS_{Ys1o}																
Bulk Storage for wheat	0.89	4.8%	0.57	12.1%	0.02	0.9%	0.08	1.9%	0.14	4.4%	0.09	1.3%	1.94	10.3%	-0.07	-1.1%
ΔPS_{Ys2o}																
Bulk Storage for barley	0.47	2.5%	-0.02	-0.3%	0.00	0.0%	0.04	1.1%	0.08	2.5%	0.05	0.7%	-0.09	-0.5%	1.07	17.1%
ΔPS_{Ys3o}																
Bulk Storage for canola	0.16	0.9%	-0.01	-0.1%	0.00	0.0%	0.00	0.1%	0.01	0.2%	0.00	0.1%	-0.03	-0.2%	-0.01	-0.2%
ΔPS_{Ys4o}																
Bulk Storage for peas	0.09	0.5%	0.00	0.0%	0.00	0.0%	0.01	0.3%	0.02	0.8%	0.02	0.2%	-0.01	-0.1%	-0.01	-0.1%
Bulk Storage subtotal	1.60	8.6%	0.55	11.6%	0.02	1.0%	0.13	3.3%	0.25	7.8%	0.16	2.3%	1.80	9.6%	0.98	15.6%
ΔPS_{Fso}																
Flour Milling	0.07	0.4%	0.03	0.6%	0.29	15.7%	0.03	0.9%	0.06	2.0%	0.04	0.6%	-0.04	-0.2%	0.00	-0.1%
ΔPS_{Sso}																
Stockfeed manufacturing	0.71	3.8%	0.19	4.0%	0.05	2.8%	0.97	24.3%	1.12	35.5%	0.74	10.7%	0.47	2.5%	-0.01	-0.1%
ΔPS_{Mso}	0.18	1.0%	-0.01	-0.2%	0.00	0.0%	0.01	0.2%	0.01	0.4%	0.01	0.1%	-0.04	-0.2%	0.03	0.6%

Malt Manufacturing																
ΔPS_{CSO} Oilseed Processing and Refining	0.06	0.3%	0.00	0.0%	0.00	0.0%	0.02	0.6%	0.04	1.4%	0.03	0.4%	-0.01	0.0%	0.00	-0.1%
Southern Region Producer Surplus:	11.63	62.8%	2.55	54.3%	0.44	24.2%	1.74	43.5%	2.55	80.7%	1.69	24.2%	11.08	58.7%	4.20	67.0%
ΔPS_{Y5} Northern Region Wheat Supplier	0.08	0.4%	0.51	11.0%	0.02	1.2%	0.11	2.6%	0.19	6.2%	0.13	1.8%	2.56	13.6%	0.00	-0.1%
ΔPS_{Y6} Northern Region Barley Supplier	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.02	0.5%	0.03	1.1%	0.02	0.3%	0.01	0.0%	0.42	6.6%
ΔPS_{Y7} Northern Region Canola Supplier	0.08	0.4%	0.00	0.0%	0.00	0.0%	0.01	0.3%	0.02	0.8%	0.02	0.2%	-0.01	-0.1%	-0.01	-0.1%
Northern region Producer surplus	0.15	0.8%	0.52	11.0%	0.02	1.3%	0.14	3.4%	0.25	8.0%	0.17	2.4%	2.55	13.5%	0.41	6.5%
Total Producer Surplus:	11.78	63.6%	3.07	65.3%	0.47	25.5%	1.88	47.0%	2.80	88.7%	1.86	26.6%	13.63	72.2%	4.60	73.5%
Overseas Consumers:																
ΔCS_{Zs1} Wheat	2.19	11.8%	0.97	20.6%	-0.01	-0.7%	0.09	2.3%	0.17	5.5%	0.12	1.7%	4.62	24.5%	-0.18	-2.8%
ΔCS_{Zs2}	0.79	4.3%	-0.04	-0.8%	0.00	-0.1%	0.00	0.0%	0.00	-0.1%	0.00	0.0%	-0.18	-0.9%	1.95	31.2%

Barley																
ΔCS_{Zs3}																
Canola	0.72	3.9%	-0.03	-0.7%	0.00	-0.1%	-0.01	-0.4%	-0.03	-0.8%	-0.02	-0.2%	-0.17	-0.9%	-0.06	-0.9%
ΔCS_{Zs4}																
Peas	0.06	0.3%	0.00	-0.1%	0.00	0.0%	0.00	-0.1%	-0.01	-0.2%	0.00	-0.1%	-0.01	-0.1%	0.00	-0.1%
ΔCS_{Ss1}																
Stockfeed	0.33	1.8%	0.09	1.8%	0.02	1.3%	0.28	7.0%	0.84	26.6%	-0.14	-2.0%	0.22	1.2%	0.00	-0.1%
ΔCS_{Ms1}																
Malt	0.10	0.6%	0.00	-0.1%	0.00	0.0%	0.00	0.1%	0.01	0.3%	0.01	0.1%	-0.02	-0.1%	0.02	0.3%
ΔCS_{Cs2}																
Canola Oil	0.07	0.4%	0.00	0.0%	0.00	0.0%	0.02	0.6%	0.04	1.3%	0.03	0.4%	-0.01	0.0%	-0.01	-0.1%
Overseas Consumers subtotal	4.27	23.0%	0.98	20.8%	0.01	0.4%	0.38	9.6%	1.03	32.5%	-0.02	-0.3%	4.45	23.6%	1.72	27.5%
Domestic Consumers:																
ΔCS_{Fs1}																
Domestic Flour	0.47	2.5%	0.20	4.2%	1.22	67.0%	0.18	4.6%	0.34	10.8%	0.23	3.3%	-0.33	-1.7%	-0.03	-0.5%
ΔCS_{Ss2}																
Stockfeed Domestic	1.73	9.3%	0.46	9.8%	0.13	7.0%	1.48	37.1%	-1.14	-36.1%	4.82	69.2%	1.15	6.1%	-0.02	-0.4%
ΔCS_{Ms2}																
Malt Domestic	0.06	0.3%	0.00	-0.1%	0.00	0.0%	0.00	0.1%	0.00	0.1%	0.00	0.0%	-0.01	-0.1%	0.01	0.2%
ΔCS_{Cs3}																
Canola Oil Domestic	0.21	1.1%	0.00	0.0%	0.00	0.1%	0.07	1.6%	0.12	3.9%	0.08	1.2%	-0.02	-0.1%	-0.02	-0.3%

Domestic Consumers Subtotal	2.47	13.4%	0.65	13.9%	1.35	74.1%	1.74	43.5%	-0.67	-21.2%	5.13	73.6%	0.79	4.2%	-0.06	-1.0%
Total Consumer Surplus	6.74	36.4%	1.63	34.7%	1.36	74.5%	2.12	53.0%	0.36	11.3%	5.11	73.4%	5.24	27.8%	1.66	26.5%
Total Economic Surplus	18.52	100.0%	4.70	100.0%	1.83	100.0%	4.00	100.0%	3.16	100.0%	6.97	100.0%	18.87	100.0%	6.26	100.0%

7.3.3 Northern Region

Table 7.5 Northern region percentage changes in prices and quantities (%)

	Scenario 1 ($t_{Xnv} = -1\%$)	Scenario 2 ($t_{Yn1o} = -1\%$)	Scenario 3 ($t_{Fno} = -1\%$)	Scenario 4 ($t_{Sno} = 1\%$)	Scenario 5 ($n_{Sn1} = 1\%$)	Scenario 6 ($n_{Sn2} = 1\%$)	Scenario 7 ($n_{Zn1} = 1\%$)	Scenario 8 ($n_{Zn2} = 1\%$)
Quantities:								
eX_{nv}	0.55	0.06	0.02	0.05	0.09	0.06	0.37	0.03
eX_{no}	0.42	0.06	0.02	0.04	0.09	0.06	0.35	0.03
eY_{n1}	0.45	0.10	0.03	0.05	0.10	0.07	0.61	0.00
eY_{n2}	0.34	0.00	0.01	0.10	0.20	0.13	-0.02	0.30
eY_{n3}	0.54	-0.01	0.00	0.02	0.04	0.03	-0.07	-0.01
eY_{n4}	0.94	-0.02	-0.01	-0.01	-0.02	-0.01	-0.13	-0.01
eY_{n1o}	0.40	0.20	0.03	0.05	0.10	0.07	0.61	0.00
eY_{n2o}	0.29	0.00	0.01	0.10	0.20	0.13	-0.01	0.29
eY_{n3o}	0.48	-0.01	0.00	0.02	0.05	0.03	-0.06	0.00
eY_{n4o}	0.88	-0.02	-0.01	-0.01	-0.02	-0.01	-0.12	-0.01
eZ_{n1}	0.75	0.20	-0.01	0.04	0.08	0.05	1.31	-0.01
eZ_{n2}	0.75	-0.02	0.00	0.01	0.01	0.01	-0.10	1.54
eZ_{n3}	0.95	-0.02	-0.01	-0.02	-0.03	-0.02	-0.13	-0.01
eZ_{n4}	0.96	-0.02	-0.01	-0.02	-0.03	-0.02	-0.13	-0.01
eZ_{n5}	0.13	0.03	0.13	0.03	0.06	0.04	-0.04	0.00
eZ_{n6}	0.31	0.08	0.02	0.13	0.26	0.18	0.22	0.00
eZ_{n7}	0.24	0.01	0.01	0.17	0.33	0.22	0.01	0.01
eZ_{n8}	0.29	0.00	0.00	0.03	0.07	0.05	-0.03	0.02
eZ_{n9}	0.32	0.00	0.00	0.07	0.14	0.09	-0.02	0.00
eZ_{n10}	0.25	0.01	0.01	0.18	0.35	0.23	0.01	0.00
eZ_{n11}	0.21	0.06	0.00	0.01	0.02	0.02	-0.02	0.00
eZ_{n12}	0.20	0.00	0.00	0.00	0.00	0.00	-0.03	-0.01

eZ_{n13}	0.22	-0.01	0.00	0.00	-0.01	-0.01	-0.03	0.00
eF_{no}	0.08	0.02	0.23	0.03	0.06	0.04	-0.02	0.00
eF_{n1}	0.11	0.03	0.18	0.03	0.06	0.04	-0.03	0.00
eF_{n2}	0.11	0.03	0.18	0.03	0.07	0.05	-0.03	0.00
eS_{no}	0.19	0.03	0.03	0.22	0.26	0.18	0.08	0.00
eS_{n1}	0.45	0.08	0.07	0.31	1.02	-0.20	0.19	0.00
eS_{n2}	0.14	0.02	0.02	0.09	-0.09	0.34	0.06	0.00
eM_{no}	0.23	0.00	0.00	0.03	0.05	0.04	-0.02	0.02
eM_{n1}	0.30	0.00	0.00	0.04	0.07	0.05	-0.03	0.02
eM_{n2}	0.09	0.00	0.00	0.01	0.02	0.01	-0.01	0.01
eC_{no}	0.26	0.00	0.00	0.06	0.13	0.09	-0.02	0.00
eC_{n1}	0.31	0.00	0.00	0.07	0.14	0.09	-0.02	0.00
eC_{n2}	0.48	0.00	0.00	0.10	0.20	0.13	-0.04	0.00
eC_{n3}	0.16	0.00	0.00	0.03	0.07	0.04	-0.01	0.00
Prices:								
ew_{nv}	-0.82	0.02	0.01	0.02	0.03	0.02	0.12	0.01
ew_{no}	0.42	0.06	0.02	0.04	0.09	0.06	0.35	0.03
ev_{n1}	-0.42	0.05	0.01	0.03	0.05	0.04	0.28	0.00
ev_{n2}	-0.45	0.01	0.01	0.04	0.09	0.06	0.07	0.10
ev_{n3}	-0.39	0.01	0.00	0.02	0.03	0.02	0.06	0.00
ev_{n4}	-0.26	0.01	0.00	0.01	0.01	0.01	0.04	0.00
ev_{n1o}	0.16	-0.92	0.01	0.02	0.04	0.03	0.24	0.00
ev_{n2o}	0.12	0.00	0.00	0.04	0.08	0.05	0.00	0.12
ev_{n3o}	0.19	0.00	0.00	0.01	0.02	0.01	-0.02	0.00
ev_{n4o}	0.35	-0.01	0.00	0.00	-0.01	0.00	-0.05	0.00
eu_{n1}	-0.15	-0.04	0.00	-0.01	-0.02	-0.01	0.74	0.00
eu_{n2}	-0.15	0.00	0.00	0.00	0.00	0.00	0.02	0.69
eu_{n3}	-0.19	0.00	0.00	0.00	0.01	0.00	0.03	0.00

eu _{n4}	-0.19	0.00	0.00	0.00	0.01	0.00	0.03	0.00
eu _{n5}	-0.41	-0.11	0.06	-0.01	-0.02	-0.02	0.17	0.00
eu _{n6}	-0.61	-0.17	-0.01	0.19	0.38	0.25	-0.51	0.01
eu _{n7}	-0.40	0.02	0.01	0.09	0.18	0.12	0.08	-0.03
eu _{n8}	-0.35	0.00	0.00	-0.04	-0.08	-0.05	0.03	-0.03
eu _{n9}	-0.40	0.01	0.00	0.03	0.06	0.04	0.06	0.00
eu _{n10}	-0.43	0.02	0.01	0.07	0.13	0.09	0.07	0.01
eu _{n11}	-0.43	-0.11	0.00	-0.02	-0.05	-0.03	0.04	0.00
eu _{n12}	-0.39	0.01	0.00	0.00	-0.01	0.00	0.05	0.02
eu _{n13}	-0.43	0.01	0.00	0.01	0.02	0.01	0.06	0.00
eg _{no}	0.05	0.01	-0.85	0.02	0.04	0.02	-0.02	0.00
eg _{n1}	-0.21	-0.05	-0.36	-0.06	-0.12	-0.08	0.07	0.00
eg _{n2}	-0.03	-0.03	-0.46	0.47	0.93	0.61	0.20	0.00
et _{no}	0.19	0.03	0.03	-0.78	0.26	0.18	0.08	0.00
et _{n1}	-0.11	-0.02	-0.02	-0.08	0.74	0.05	-0.05	0.00
et _{n2}	-0.27	-0.05	-0.04	-0.19	0.19	0.32	-0.11	0.00
en _{no}	0.23	0.00	0.00	0.03	0.05	0.04	-0.02	0.02
en _{n1}	-0.08	0.00	0.00	-0.01	-0.02	-0.01	0.01	-0.01
en _{n2}	-0.18	0.00	0.00	-0.02	-0.04	-0.03	0.02	-0.01
ed _{no}	0.26	0.00	0.00	0.06	0.13	0.09	-0.02	0.00
ed _{n1}	-0.60	0.05	0.03	0.36	0.72	0.48	0.18	0.01
ed _{n2}	-0.12	0.00	0.00	-0.03	-0.05	-0.03	0.01	0.00
ed _{n3}	-0.32	0.00	0.00	-0.07	-0.14	-0.09	0.02	0.00

Table 7.6 Northern Region economic surplus changes (\$ million) and Percentage Shares of total surplus changes (%) to various industry groups

	Scenario 1 ($t_{Xnv} = -1\%$)		Scenario 2 ($t_{Yn1o} = -1\%$)		Scenario 3 ($t_{Fno} = -1\%$)		Scenario 4 ($t_{Sno} = -1\%$)		Scenario 5 ($n_{Sn1} = 1\%$)		Scenario 6 ($n_{Sn2} = 1\%$)		Scenario 7 ($n_{Zn1} = 1\%$)		Scenario 8 ($n_{Zn2} = 1\%$)	
	\$m	%	\$m	%	\$m	%	\$m	%					\$m	%		
ΔPS_{Xno}	4.26	21.5%	0.60	18.9%	0.19	3.9%	0.45	9.2%	0.90	21.5%	0.59	6.5%	3.49	35.6%	0.28	35.7%
ΔPS_{Xnv}	3.62	18.2%	0.42	13.2%	0.13	2.7%	0.31	6.4%	0.62	15.0%	0.41	4.5%	2.44	24.9%	0.19	24.9%
Farm subtotal	7.88	39.7%	1.02	32.1%	0.32	6.5%	0.76	15.7%	1.52	36.5%	1.00	11.0%	5.93	60.5%	0.47	60.6%
ΔPS_{Yn1o}																
Storage for wheat	0.51	2.5%	0.25	8.0%	0.04	0.8%	0.07	1.4%	0.13	3.2%	0.09	1.0%	0.78	8.0%	0.00	-0.6%
ΔPS_{Yn2o}																
Storage for barley	0.09	0.5%	0.00	0.0%	0.00	0.0%	0.03	0.7%	0.06	1.6%	0.04	0.5%	0.00	0.0%	0.10	12.3%
ΔPS_{Yn3o}																
Storage for canola	0.10	0.5%	0.00	-0.1%	0.00	0.0%	0.00	0.1%	0.01	0.2%	0.01	0.1%	-0.01	-0.1%	0.00	-0.1%
ΔPS_{Yn4o}																
Storage for chickpeas	0.11	0.6%	0.00	-0.1%	0.00	0.0%	0.00	0.0%	0.00	-0.1%	0.00	0.0%	-0.01	-0.1%	0.00	-0.2%
Bulk Storage subtotal	0.81	4.1%	0.25	7.9%	0.04	0.8%	0.10	2.1%	0.21	4.9%	0.14	1.5%	0.75	7.6%	0.09	11.4%
ΔPS_{Fno}																
Flour Milling	0.26	1.3%	0.07	2.1%	0.73	15.1%	0.09	1.9%	0.18	4.4%	0.12	1.3%	-0.08	-0.8%	0.00	-0.3%
ΔPS_{Sno}																
Stockfeed manufacturing	0.95	4.8%	0.17	5.3%	0.14	2.8%	1.10	22.5%	1.30	31.2%	0.86	9.4%	0.40	4.0%	0.01	1.0%
ΔPS_{Mno}	0.11	0.5%	0.00	0.0%	0.00	0.0%	0.01	0.3%	0.03	0.6%	0.02	0.2%	-0.01	-0.1%	0.01	1.1%

Malt Manufacturing																	
ΔPS_{Cno} Oilseed Processing and Refining	0.09	0.5%	0.00	0.0%	0.00	0.0%	0.02	0.5%	0.05	1.1%	0.03	0.3%	-0.01	-0.1%	0.00	-0.1%	
Producer Surplus subtotal:	10.92	50.9%	1.75	47.4%	1.26	25.3%	2.20	44.8%	3.48	78.7%	2.30	23.8%	7.73	71.2%	0.66	73.7%	
Overseas Consumers:																	
ΔCS_{Zn1} Wheat Export	1.47	7.4%	0.39	12.3%	-0.02	-0.5%	0.08	1.6%	0.16	3.8%	0.10	1.1%	2.60	26.5%	-0.02	-1.9%	
ΔCS_{Zn2} Barley Export	0.12	0.6%	0.00	-0.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	-0.02	-0.2%	0.24	31.1%	
ΔCS_{Zn3} Canola Export	0.35	1.8%	-0.01	-0.3%	0.00	-0.1%	-	0.01	-0.1%	-0.01	-0.3%	-0.01	-0.1%	-0.05	-0.5%	0.00	-0.5%
ΔCS_{Zn4} Chickpeas Export	0.63	3.1%	-0.01	-0.5%	0.00	-0.1%	-	0.01	-0.2%	-0.02	-0.5%	-0.01	-0.2%	-0.09	-0.9%	-0.01	-0.9%
ΔCS_{Sn1} Stockfeed Export	0.47	2.4%	0.08	2.6%	0.07	1.4%	0.32	6.6%	1.06	25.4%	-0.21	-2.3%	0.19	2.0%	0.00	0.5%	
ΔCS_{Mn1} Malt Export	0.06	0.3%	0.00	0.0%	0.00	0.0%	0.01	0.2%	0.02	0.4%	0.01	0.1%	-0.01	-0.1%	0.01	0.7%	
ΔCS_{Cn2}	0.11	0.6%	0.00	0.0%	0.00	0.0%	0.02	0.5%	0.05	1.2%	0.03	0.4%	-0.01	-0.1%	0.00	-0.1%	

Canola Oil Export																
Overseas Consumers subtotal	3.22	16.2%	0.45	14.0%	0.04	0.8%	0.42	8.5%	1.25	29.9%	-0.09	-0.9%	2.63	26.8%	0.23	28.9%
ΔCS_{Fn1} Domestic Flour	1.90	9.5%	0.48	15.3%	3.20	66.5%	0.53	10.8%	1.05	25.3%	0.69	7.6%	-0.60	-6.1%	-0.02	-2.0%
ΔCS_{Sn2} Domestic Stockfeed	2.47	12.4%	0.43	13.7%	0.36	7.4%	1.70	34.9%	-1.68	-40.4%	6.15	67.5%	1.02	10.4%	0.02	2.6%
ΔCS_{Mn2} Domestic Malt	0.04	0.2%	0.00	0.0%	0.00	0.0%	0.00	0.1%	0.01	0.2%	0.01	0.1%	0.00	0.0%	0.00	0.4%
ΔCS_{Cn3} Domestic Canola Oil	0.33	1.7%	0.00	0.0%	0.00	0.1%	0.07	1.4%	0.14	3.4%	0.09	1.0%	-0.02	-0.3%	0.00	-0.4%
Northern Region Domestic Consumers Subtotal	4.73	23.8%	0.92	29.0%	3.56	74.0%	2.30	47.3%	-0.48	-11.6%	6.94	76.3%	0.39	4.0%	0.00	0.6%
ΔCS_{Zn11} Wheat to Southern Region	1.20	6.0%	0.32	10.0%	0.00	0.0%	0.07	1.4%	0.13	3.2%	0.09	1.0%	-0.11	-1.1%	-0.01	-1.6%
ΔCS_{Zn12} Barley to Southern Region	0.19	1.0%	0.00	-0.1%	0.00	0.0%	0.00	0.0%	0.00	0.1%	0.00	0.0%	-0.02	-0.3%	-0.01	-1.0%

ΔCS_{zn13} Canola to Southern Region	0.43	2.1%	-0.01	-0.3%	0.00	-0.1%	-	-0.2%	-0.02	-0.4%	-0.01	-0.1%	-0.06	-0.6%	0.00	-0.6%
Southern Region Consumer Surplus Subtotal	1.82	9.2%	0.30	9.6%	0.01	-0.1%	0.06	1.3%	0.12	2.9%	0.08	0.9%	-0.19	-2.0%	-0.02	-3.2%
Total Consumer Surplus	9.77	49.1%	1.67	52.6%	3.60	74.7%	2.78	57.0%	0.89	21.3%	6.93	76.2%	2.82	28.8%	0.21	26.3%
Total Economic Surplus	19.87	100.0%	3.17	100.0%	4.82	100.0%	4.87	100.0%	4.16	100.0%	9.10	100.0%	9.81	100.0%	0.78	100.0%

7.4 Summary

This chapter presents the base simulation results for eight hypothetical RD&E investment scenarios. For each scenario, percentage changes in prices and quantities for each scenario in all industry sectors are reported for each of the three regions. The resulting economic welfare implications, including the distribution of economic benefits are presented. The results of three investment scenarios (Scenarios 1, 4 and 7), each of which target different segments of the supply chain, are discussed in detail. The results demonstrate that the same investment scenario can have different economic and distributional impacts depending on the cropping region. In the next chapter these results are considered further.

Chapter 8 Discussion and Comparisons

8.1 Introduction

The results in the previous chapter show the differences in both magnitude and distribution of the likely benefits arising from different investment scenarios across different regions. This would be of interest to the GRDC for two reasons.

Firstly, one of the GRDC's key aims is provide the best return on investment in order to drive the profitability of Australia's grain growing businesses (GRDC, 2019). Having an understanding of the returns associated with different RD&E investment scenarios is therefore useful during the investment allocation and priority setting process. Similarly, producers also have a vested interest in the efficient allocation of funds to maximise returns to their industry and communities.

Secondly, having an understanding of the distributional impacts associated with the various investment scenarios can provide insight into who should pay for these investments. The GRDC currently obtains its funding by a grower levy along with matching funding from the Australian Government. This levy is based on the net farm gate value of the annual production of key crops (GRDC, 2019). The results from this study could potentially be of interest to the GRDC in determining the appropriateness of its current levy structure.

Section 8.2 provides some comments and qualifications around the interpretation of the results. Section 8.3 provides commentary around conclusions that can be drawn between the differences in results generated under each investment scenario. Section 8.4 provides a comparison of the differences in results between each region. Section 8.5 discusses the implications of the results for producers.

8.2 Note around Interpreting the Results

It should be noted that an EDM only provides a framework for assessing the potential benefits arising from different RD&E investment scenarios. The investment costs required to achieve the 1% shifts in supply and demand (i.e. 1% cost reduction or 1% increase in consumers' willingness to pay) cannot be answered under this framework. Therefore, deciding which investment scenario should be preferred over another requires information on the costs of each investment. In this regard,

when comparing the absolute monetary returns arising from the different investment scenarios using an EDM framework alone, one must make the assumption that the investment costs required to generate each 1% shifts in supply and demand are all equal (i.e. same investment efficiency). When comparing the same investment scenario between different regions, the same assumption must be made in that it would cost the same in each region to bring about a 1% reduction in costs under Scenario 1 for instance.

It should also be noted that the distribution of total benefits among different industry groups for a particular scenario is independent of the size of the initial shift. For example, the farm production share of total benefits in Scenario 1 in the western region is the same (59.4%) regardless of whether the innovation reduces costs by 1% or 5%. This is due to the assumption of parallel shifts in supply and demand.

This section discusses and compares the results between the eight different investment scenarios (as defined in Section 6.4) as well as the different cropping regions.

8.3 General Comparisons between Investment Scenarios

When comparing the results between the different investment scenarios, a few observations can be made.

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, with the size determined by the products of prices and quantities. As such, a 1% shift in the demand or supply of a market with high gross revenue will yield higher total returns than a 1% shift in a market with low gross revenue. For instance, the total economic benefits arising from the exogenous shock in Scenario 1 is significant for each region, because of the substantial total market value at farm gate. In comparison, the benefits arising from the exogenous shock in Scenario 4 are relatively minor in comparison, because of the low total market value in stockfeed manufacturing. This effect can also be observed for the same investment scenarios between regions as well. For instance, the significant gross revenue of the export wheat market in the western region (\$2,593 million) sees a 1% increase in overseas consumers' willingness to pay (Scenario 7) generating substantial economic returns to the industry (\$26.07 million). In contrast, the same investment scenario in the northern region is estimated to generate only \$9.81 million because of the comparatively smaller size of the

export wheat market in the northern region (\$981 million). A comparison of the rankings of the absolute total returns in millions of dollars resulting from each investment scenario is listed in Table 8.1 below. These rankings can only be used as a comparison of preference between the different investment scenarios under the assumption of equal investment efficiency.

For small exogenous shifts, the changes in total economic surplus are predominantly determined by the magnitude of the initial percentage shifts ($t_{(.)}'s$ and $n_{(.)}'s$) and the sizes of the markets where the initial shifts occur (determined by the products of prices and quantities). This can be observed from the formulas used to calculate the total economic surplus for each of the investment scenarios presented in Table 6.8. Because of this, a 1% shift in any market should generate a total surplus change that is very close to 1% of the gross value of production of the innovating market. This can be used as a simple plausibility check. For instance, using Scenario 7 (export wheat research) in the western region as an example, the total surplus change generated is \$26.07 million per annum which is calculated by:

$$\begin{aligned}\Delta TS &= u_{w1}^{(1)} Z_{w1}^{(1)} n_{zw1} (1 + 0.5EZ_{w1}) \\ &= 310 \times 8,367,338 \times 0.01 \times (1 + 0.5 \times 0.0150) \\ &= \$26.07 \text{ Million}\end{aligned}\tag{8.1}$$

This figure can then be compared with a 1% of the total market value for export wheat given by:

$$\begin{aligned}u_{w1}^{(1)} Z_{w1}^{(1)} n_{zw1} &= 310 \times 8,367,338 \times 0.01 \\ &= \$25.94 \text{ million}\end{aligned}\tag{8.2}$$

As can be seen, Equations 8.1 and 8.2 above are very close in magnitude, as the total surplus formula is primary driven by the total size of the market where the innovation occurs ($u_{w1}^{(1)} Z_{w1}^{(1)}$) along with the size of the shifter variable (n_{zw1}). This is a simple and useful plausibility check.

Table 8.1 Returns to industry arising from each investment scenario by region

Rank	Western	Southern	Northern
1	Scenario 7 (\$26.07m)	Scenario 7 (\$18.87m)	Scenario 1 (\$19.87m)
2	Scenario 1 (\$24.23m)	Scenario 1 (\$18.52m)	Scenario 7 (\$9.81m)
3	Scenario 8 (\$6.77m)	Scenario 6 (\$6.97m)	Scenario 6 (\$9.10m)
4	Scenario 2 (\$4.72m)	Scenario 8 (\$6.26m)	Scenario 4 (\$4.87m)
5	Scenario 6 (\$1.78m)	Scenario 2 (\$4.70m)	Scenario 3 (\$4.82m)
6	Scenario 4 (\$0.92m)	Scenario 4 (\$4.00m)	Scenario 5 (\$4.16m)
7	Scenario 5 (\$0.81m)	Scenario 5 (\$3.16m)	Scenario 2 (\$3.17m)
8	Scenario 3 (\$0.52m)	Scenario 3 (\$1.83m)	Scenario 8 (\$0.78m)

The distribution of benefits depends on the:

- Size of the market where the RD&E investment occurs; and
- Market elasticities.

Generally speaking, the distribution of benefits is influenced largely by the market in which the RD&E occurs as this market stands to reap a considerable share of total benefits. The larger the value of this market, the greater its share of total benefits. For instance, on-farm productivity research (Scenario 1) will generate a substantial share of benefits to farm producers because the innovation is in the producers' market segment and gross revenue of this segment is large. In comparison, research in stockfeed manufacturing (Scenario 4) would see a greater share of benefits accruing to stockfeed manufacturers themselves with less benefits flowing back to primary producers.

The distribution of benefits also depends on the elasticities of supply and demand in the market segments. In particular (i) the elasticities of input supply in innovating producer and processor markets and (ii) elasticities of final demand by domestic and export consumers. For the case of productivity enhancing research that induces an exogenous input supply shock, the more elastic the input supply in an innovating producer/processing market, the less benefits will accrue to the innovating market itself, enabling more benefits to flow to the final consumers of its market outputs. As such, participants in the innovating market will stand to benefit more if its input supply is inelastic, as more producer surplus will be captured. For instance, technology improving research in stockfeed manufacturing (Scenario 4) also generates a substantial share of benefits to the final

consumers of stockfeed. The degree to which these final consumers benefit is determined by their demand elasticities. A significant share of benefits accrues to domestic consumers (37.5% in the western region) because of the small elasticity of domestic demand (-0.5), whereas a smaller share of benefits accrues to overseas consumers (7.1% in the western region) due to larger elasticity of export demand (-4). For the case of quality enhancing research represented by an exogenous demand side shock to final consumers, a smaller share of benefits accrue to the consumers when their demand is price-elastic, enabling more benefits to flow back to grain processors and primary producers. On the other hand, when consumer demand is price-inelastic, a larger share of benefits will accrue to these consumers.

8.4 Comparisons between Regions

As presented in Table 8.1 above, a number of differences can be observed in the results between the three cropping regions.

The western region grains industry is characterised by a short supply chain, where most of grain production is exported. The large volume of grain exported ensures that, when investments in RD&E are targeted towards upstream farm production (Scenario 1) or the overseas commodity market (Scenario 7), some of the total benefits are enjoyed by overseas consumers. Still, a high price elasticity of demand for export grains (-5) ensures that the farm production sector receives the majority of total benefits, and these benefits outweigh the share of benefits received by overseas consumers.

The southern region grains industry exports a majority of its grain production. As such, a similar picture to the western region is observed for Scenarios 1 and 7, where the majority of total benefits go to the farm production sector, with some benefits also going to overseas consumers as a result of the high price elasticity of demand for export grains. However, the total industry value of grain is smaller when compared to the western region, and because of this, total economic surplus arising from these two investment scenarios is smaller than in the western region. As the southern region also obtains some of its grain from the northern region, research that increases the demand of export grain (Scenario 7) also triggers more grain to come from the northern region to satisfy the greater demand, therefore benefiting the northern region grains industry. Also, as more of southern grain is processed domestically compared to the western region, research in the processing markets (Scenario 4) will also generate greater overall economic returns to the industry.

The northern region grains industry is more domestically oriented compared with the western and southern regions, with a large portion of grain production processed domestically or sold to other states in the southern region. For this reason, research aiming at the export grain market (Scenario 7) will generate far lower economic benefits to the industry (\$9.81 million). In addition, research that reduces the costs of farm production (Scenario 1) will benefit consumers in the southern region. Also, the larger market size of the domestic processing markets in the northern region means that research that aims at domestic processors (Scenario 4) also generate relatively higher overall returns to the industry compared to the western and southern regions.

Table 8.2 below provides a comparison of the initial shifts required to bring about the same absolute returns in the western region for Scenario 1. Greater percentage shifts are required by the southern and northern regions to generate the same economic returns for a 1% shift in the western region. This is due to the smaller industry sizes of the southern and northern regions compared to the western region.

Table 8.2 Percentage shifts required to provide the same total returns as western region from Scenario 1

	Western	Southern	Northern
Total Returns (\$m)	24.23	24.23	24.23
Initial shifts required (%)	1.00	1.31	1.22

8.5 Benefits to Producers

One of the overarching goals of the GRDC is to maximise the impact of RD&E investment on the profitability of Australian grain growers. As shown in Table 2.4, the GRDC uses levies it collects from producers to invest in a number of priority areas to help support production, sustainability and profitability in the industry. Over half of GRDC's expenditure is directed towards research in productivity and value adding. Results from EDM analysis can reveal the types of RD&E investment that will yield the greatest net and distribution of returns to grain growers in each region.

Previous studies have compared the returns between on-farm and off-farm research. Alston and Scobie's (1983) comment on Freebairn, Davis and Edwards (1982) highlighted that under fixed proportions, the distribution of benefits is independent of the stage in which the innovation is

applied in the system. In other words, under the scenario where substitution and transformation elasticities across all markets in the industry are zero, all industry groups should be indifferent to where investment funds are spent. However, when input substitution and output transformation elasticities are non-zero as is the case with the EDMs in this study, the distribution of benefits will indeed vary depending on where the RD&E occurs in the industry supply chain.

Intuitively, producers should stand to gain a significant share of total benefits from farm production research (Scenario 1). However, as can be seen in Table 8.3, although producers across all regions receive a substantial share from on-farm research (Scenario 1), quality enhancing research in the export grain market can generate even greater shares of benefits to producers. This is largely due to the elastic demand faced by overseas consumers of grain exports, enabling much of the benefits to flow back to the producers. Consequently, research that enhances the quality of export wheat provides the most share of benefits to farmers in the western region compared to the other scenarios examined. In the southern and northern regions, quality-enhancing research for export barley (Scenario 8) provides the greatest share compared to other examined scenarios.

Quality-enhancing research that targets export stockfeed also generates substantial returns for producers in all three regions due to the small market value of the stockfeed export market along with the high elasticity of demand faced by overseas consumers (-4).

Research targeting the bulk storage market for wheat (Scenario 2) also generates a large share of benefits to producers. This is due to the highly elastic demand for export wheat along with the moderately high elasticity of supply for inputs in the storage sector (-2.5), ensuring that a substantial proportion of benefits will flow back to producers instead of overseas consumers and bulk storage owners.

Table 8.4 provides a ranking of each investment scenario by the percentage share of total benefits it generates to farm production under each region. As mentioned before, the absolute returns of alternative investment scenarios are directly comparable only under the assumption of equal investment efficiency. However, the share of total benefits among different industry groups resulting from different investment scenarios do not require information on the costs of investment and are directly comparable. This is because the distribution of total benefits among different industry groups for a particular scenario is the same regardless of the size of the initial shift.

Table 8.3 Absolute returns to farm production by region

Rank	Western	Southern	Northern
1	Scenario 7 (\$16.01m)	Scenario 1 (\$9.00m)	Scenario 1 (\$7.88m)
2	Scenario 1 (\$14.40m)	Scenario 7 (\$8.89m)	Scenario 7 (\$5.93m)
3	Scenario 8 (\$3.59m)	Scenario 8 (\$3.20m)	Scenario 5 (\$1.52m)
4	Scenario 2 (\$2.64m)	Scenario 2 (\$1.80m)	Scenario 2 (\$1.02m)
5	Scenario 5 (\$0.35m)	Scenario 5 (\$1.06m)	Scenario 6 (\$1.00m)
6	Scenario 5 (\$0.23m)	Scenario 6 (\$0.70m)	Scenario 4 (\$0.76m)
7	Scenario 4 (\$0.17m)	Scenario 4 (\$0.57m)	Scenario 8 (\$0.47m)
8	Scenario 3 (\$0.03m)	Scenario 3 (\$0.08m)	Scenario 3 (\$0.32m)

Table 8.4 Share of benefits to farm production by region

Rank	Western	Southern	Northern
1	Scenario 7 (61.4%)	Scenario 8 (51.1%)	Scenario 8 (60.6%)
2	Scenario 1 (59.4%)	Scenario 1 (48.6%)	Scenario 7 (60.5%)
3	Scenario 2 (56.0%)	Scenario 7 (47.1%)	Scenario 1 (39.7%)
4	Scenario 8 (53.1%)	Scenario 2 (38.3%)	Scenario 5 (36.5%)
5	Scenario 5 (43.3%)	Scenario 5 (33.5%)	Scenario 2 (32.1%)
6	Scenario 4 (18.5%)	Scenario 4 (14.3%)	Scenario 4 (15.7%)
7	Scenario 6 (13.0%)	Scenario 6 (10.1%)	Scenario 6 (11.0%)
8	Scenario 3 (6.3%)	Scenario 3 (4.6%)	Scenario 3 (6.5%)

8.6 Summary

In this chapter the insights and conclusions that can be drawn from the results reported in Chapter 7 have been explored.

The size of the total economic benefits derived from any investment scenario depends on the size of the market where the outcomes of the investment in RD&E are adopted. Aiming research at a market with high gross revenue will generate greater returns to the industry as a whole.

The distribution of benefits depends on the (i) size of the market where the RD&E investment occurs and the (ii) market elasticities of supply and demand. Generally speaking, the market in which the RD&E is adopted gains a significant share of total benefits, with this share increasing, as the size of the market gets larger. Market elasticities of supply and demand influence the distributional impacts, in particular, the elasticities of input supply in the innovating producer and processing markets, along with the elasticities of final demand.

Regional differences in the results are observed for each of the hypothetical investment scenarios. This is because of the inherent differences between each region. The western region grains industry is characterised by a short supply chain, where the vast majority of grain production is exported. This means that overseas consumers will gain a large share of total benefits alongside farm production. The southern region is export oriented, although smaller in terms of its total industry value. The northern region, on the other hand, is comparatively domestic oriented, with a large portion of its grain production processed domestically. Because of this, research aimed at overseas demand will result in much lower levels of benefits compared to the western and southern regions, whereas research targeting the domestic processing markets will result in higher levels of benefits compared with the other two regions.

As the GRDC derives the majority of its funding from producer contributed levies. It is therefore desirable for investments to provide significant shares of benefits to producers. The results show that for all three regions, Scenarios 1, 2, 5, 7 and 8 deliver the greatest shares of benefits for producers.

One qualification to be noted is that EDMs only estimates the potential benefits arising from different RD&E investment scenarios. The investment costs required to achieve the 1% shifts in

supply and demand cannot be answered under such a framework. Therefore, comparisons between the absolute returns of different investment scenarios can only be made under the assumption of equal investment cost efficiency. However, comparisons of the shares of benefits arising for any particular industry group can be directly compared between investment scenarios without the requirement of such an assumption.

Chapter 9 Sensitivity Analysis

9.1 Introduction

The base results reported in Chapter 7 indicated estimates of the magnitude and distribution of total benefits generated by different hypothetical RD&E investments. These results were generated using a set of base input parameters selected to calibrate the model, namely data on prices and quantities, along with the values chosen for the elasticities specified in Section 6.3.

For small exogenous shifts, as applied in the different RD&E scenarios, the changes in total economic surplus are predominantly governed by the magnitude of the initial percentage shifts (t_{ij} 's and n_{ij} 's) and the sizes of the markets where the initial shifts occur (determined by the products of prices and quantities). The distributional impacts among the industry groups depend on the market elasticities. The precision of the results hinges heavily on the reliability of the input values chosen, as different specifications generate different results.

When calibrating the initial equilibrium prices and quantities used in the EDM system, reliable data is generally available through a variety of sources as detailed in Chapter 4. For the case of price elasticities however, there is considerable uncertainty around their true values. The price elasticity values used to obtain the results have been specified based on previously published estimates along with some subjective judgement. Robust estimates for elasticities have been difficult to obtain for a host of reasons. Of the price elasticity estimates published in literature, the majority are measured at the retail level rather than at the farm gate and are not geographically differentiated. Further, many of the previous estimates reviewed in this study are dated and may not reflect current Australian agriculture. The degree of uncertainty around the specified elasticity values undermines the robustness of the calculated distributional impacts. Given the uncertainty of the parameters, this chapter applies sensitivity analysis to examine the sensitivity of the results of the base model with respect to variations in parameter values.

In Section 9.2, discrete sensitivity analysis on a select number of market elasticities is performed to demonstrate the divergence in final results when different elasticity values are chosen. To test the validity of the EDMs under the scenario of fixed proportions, the model is calibrated by setting all

input substitution (σ) and product transformation (τ) elasticities to zero. In addition, the sensitivity of the results in response to changes to prices and quantities is also examined.

In Section 9.3, stochastic sensitivity analysis is conducted. This form of sensitivity analysis provides a treatment of the uncertainty present in market elasticity values and is based on the method presented by Zhao *et al.* (2000a). This involves replacing point estimates for uncertain elasticities with probability distributions, with subsequent results provided in the form of probability distributions for the estimated changes in economic surplus for each industry group market.

9.2 Discrete Sensitivity Analysis

A rudimentary approach in treating uncertainty in parameter values is to perform discrete sensitivity analysis. This involves discretely adjusting parameter values and observing and comparing the impacts on results. This conventional approach to sensitivity analysis is useful in demonstrating how results can vary largely depending on the values chosen for key parameters.

9.2.1 Supply and Demand Elasticities

The distributional impacts obtained in the base models presented in Chapter 7 are highly influenced by the values chosen for the elasticities of supply and demand as they determine the share of total benefit accrued to the various factor suppliers and consumer groups.

To highlight and test this with an example, Table 9.1 provides a condensed summary of the distributional impacts for all regions when the value for the supply elasticity of variable farm inputs is increased and decreased (from a base value of 3.0) under two chosen RD&E investment scenarios, with all other parameter values remaining unchanged from their base values.

The results show that the farm production market gains a larger share of total benefits when the elasticity of supply of variable farm inputs is more inelastic (smaller in magnitude), and a smaller share of benefits when the same elasticity is more elastic (larger in magnitude). This can be observed in the case of Scenario 1, where the farm production market captures a greater share of benefits under a more inelastic supply ($\varepsilon = 1.0$), allowing less benefits to be accrued to other industry groups compared to the base scenario where $\varepsilon = 3.0$. Conversely, when the supply of farm variable inputs is more elastic ($\varepsilon = 5.0$), farm producers receive a smaller share of benefits, as more benefits

flow to overseas and domestic consumers. This is also the case under Scenario 7, as the farm production share of benefits increases as the supply of variable farm inputs becomes more inelastic, and decreases as the elasticity becomes more elastic as more benefits flow to overseas and domestic consumers. Under this scenario, overseas consumers gain a far greater share benefits than domestic consumers. This is due to output transformation possibilities occurring at various stages in production and distribution, ensuring that (i) more wheat is produced in favour of other grains; and (ii) more wheat is exported in favour of being used in the domestic processing markets. When the supply of variable farm inputs is sufficiently inelastic, this can also cause a decrease in domestic consumers' surplus as is the case for the northern region.

Similarly, Table 9.2 provides a condensed summary of the distributional impacts for all regions when the value for the demand elasticity of wheat exports is adjusted (from a base value of 3.0) under the same two RD&E investment scenarios, with all other parameter values remaining unchanged from their base values. The results also show that overseas consumers gain a larger share of total benefits when demand is less elastic ($\eta = -2.5$) and receive a smaller share of benefits when demand is more elastic ($\eta = -7.5$).

Table 9.1 Sensitivity of distributional impacts to changes in the supply elasticity for farm variable inputs (expressed in share of total benefits)

Scenario 1 $\varepsilon = 3.0$ (Base)				$\varepsilon = 1.0$			$\varepsilon = 5.0$		
Farm production research									
	Western	Southern	Northern	Western	Southern	Northern	Western	Southern	Northern
Farm production	59.4%	48.6%	39.7%	73.4%	64.2%	55.8%	54.7%	43.7%	34.9%
Overseas consumers	26.9%	23.0%	16.2%	17.6%	16.0%	11.9%	30.1%	25.3%	17.5%
Domestic consumers	3.5%	13.4%	23.8%	2.3%	9.3%	17.5%	3.9%	14.6%	25.7%
Scenario 7 $\varepsilon = 3.0$ (Base)				$\varepsilon = 1.0$			$\varepsilon = 5.0$		
Export Wheat Research									
	Western	Southern	Northern	Western	Southern	Northern	Western	Southern	Northern
Farm production	61.4%	47.1%	60.5%	74.8%	61.0%	82.5%	56.8%	42.8%	54.0%
Overseas consumers	27.2%	23.6%	26.8%	18.4%	17.4%	20.9%	30.3%	25.5%	28.5%
Domestic consumers	1.4%	4.2%	4.0%	0.2%	0.6%	-4.7%	1.8%	5.3%	6.5%

Table 9.2 Sensitivity of distributional impacts to changes in the demand elasticity for export wheat

Scenario 1 $\eta = -5.0$ (Base)				$\eta = -2.5$			$\eta = -7.5$		
Farm production research									
	Western	Southern	Northern	Western	Southern	Northern	Western	Southern	Northern
Farm production	59.4%	48.6%	39.7%	51.7%	44.1%	36.1%	63.1%	50.6%	41.3%
Overseas consumers	26.9%	23.0%	16.2%	36.0%	30.3%	20.5%	22.5%	19.8%	14.2%
Domestic consumers	3.5%	13.4%	23.8%	3.3%	13.0%	23.6%	3.6%	13.5%	23.9%
Scenario 7 $\eta = -5.0$ (Base)				$\eta = -2.5$			$\eta = -7.5$		
Export Wheat Research									
	Western	Southern	Northern	Western	Southern	Northern	Western	Southern	Northern
Farm production	61.4%	47.1%	60.5%	47.2%	37.9%	47.8%	68.2%	51.3%	66.3%
Overseas consumers	27.2%	23.6%	26.8%	44.0%	38.6%	42.1%	19.2%	16.8%	19.7%
Domestic consumers	1.4%	4.2%	4.0%	1.1%	3.4%	3.1%	1.5%	4.5%	4.3%

9.2.2 Input Substitution and Output Transformation Elasticities

The distributional impacts of the results are also influenced by the values chosen for the input substitution and output transformation elasticities. The input substitution elasticity measures the degree of substitutability between two inputs in a market in response to changes in relative prices. Similarly, the output transformation elasticity measures the responsiveness in the output mix between two market outputs in response to changes in their relative prices.

To test the impacts that these elasticity values have on the results, all three EDMs were experimentally re-run by setting all input substitution (σ) and product transformation (τ) elasticities to zero. Under this condition, inputs in all markets are used in fixed proportions (no input substitution) and all market outputs are produced in fixed proportions (no output substitution). These results are summarised in Tables 9.3 to 9.5 below.

As can be observed, the distribution (percentage share) of benefits for industry groups remains the same for any 1% exogenous shock (demand or supply) applied to the system. Impacts on the total economic surplus are either small or negligible when compared to the total surplus figures in the base results reported in Chapter 7. This is to be expected, as changing the input substitution and product transformation elasticities should only have an impact on the distribution of benefits and not the magnitude of total benefits.

This important result is consistent with Alston and Scobie's (1983) comment on Freebairn, Davis and Edwards (1982), which highlighted that under fixed proportions, the distribution of benefits is independent of the market in which the innovation takes place. This test demonstrates the proper functioning of the model.

When comparing these results to the original base model results in Chapter 7, it is clear that by allowing substitution possibilities, a greater share of total return accrues to the market where the initial exogenous shock occurs. For instance, under Scenario 7, quality enhancing research increases the willingness to pay by overseas consumers and induces an upwards shift in demand for export wheat (Y_1). This causes the derived input demand curve for wheat going into the wheat storage market to also shift upwards, driving up the farm gate price of wheat. The higher farm gate price of wheat triggers a decrease in production supply of other grains (Y_2, Y_3, Y_4). The extent to which more wheat is produced depends on the elasticity of transformation between wheat and other grains,

with a higher magnitude corresponding to greater substitutability between outputs. As the elasticity of transformation between wheat and other grains at the farm gate is set at a high -3.0 in the base model, this results in a greater increase in wheat production and a greater decrease in other grains produced. Further output transformation possibilities occur beyond farm production where wheat can either be directly exported or processed domestically. As the elasticity of transformation between export wheat and wheat used for domestic milling purposes is high ($\tau_{Z1,Z5} = -3.0$), this results in a greater increase in wheat destined for export due to greater profitability driven by higher overseas demand. These two substitution effects result in overseas wheat consumers gaining a greater share of benefits in the base model compared to the scenario of zero substitutability (e.g. 30.0% of total benefits in the base run versus 12.8% in the fixed-proportions run for the Western Region).

Table 9.3 Experimental results for model validation when all input substitution and output transformation elasticities are set to zero ($\sigma, \tau = 0$), western region

	Scenario 1 ($t_{XWV} = -1\%$)		Scenario 2 ($t_{YW10} = -1\%$)		Scenario 3 ($t_{FW0} = -1\%$)		Scenario 4 ($t_{SW0} = -1\%$)		Scenario 5 ($n_{SW1} = 1\%$)		Scenario 6 ($n_{SW2} = 1\%$)		Scenario 7 ($n_{ZW1} = 1\%$)		Scenario 8 ($n_{ZW2} = 1\%$)	
	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%
ΔPS_{XW0}	7.36	30.4%	1.43	30.4%	0.16	30.4%	0.28	30.4%	0.24	30.4%	0.54	30.4%	7.90	30.4%	2.05	30.4%
ΔPS_{XWV}	4.83	19.9%	0.94	19.9%	0.10	19.9%	0.18	19.9%	0.16	19.9%	0.35	19.9%	5.18	19.9%	1.34	19.9%
Farm subtotal	12.18	50.3%	2.37	50.3%	0.26	50.3%	0.46	50.3%	0.40	50.3%	0.89	50.3%	13.09	50.3%	3.39	50.3%
ΔPS_{YW10}																
Bulk Storage for Wheat	1.13	4.7%	0.22	4.8%	0.02	4.7%	0.04	4.7%	0.04	4.7%	0.08	4.7%	1.21	4.7%	0.31	4.7%
ΔPS_{YW20}																
Bulk Storage for Barley	0.52	2.2%	0.10	2.2%	0.01	2.2%	0.02	2.2%	0.02	2.2%	0.04	2.2%	0.56	2.2%	0.15	2.2%
ΔPS_{YW30}																
Bulk Storage for Canola	0.19	0.8%	0.04	0.8%	0.00	0.8%	0.01	0.8%	0.01	0.8%	0.01	0.8%	0.21	0.8%	0.05	0.8%
ΔPS_{YW40}																
Bulk Storage for Lupins	0.05	0.2%	0.01	0.2%	0.00	0.2%	0.00	0.2%	0.00	0.2%	0.00	0.2%	0.05	0.2%	0.01	0.2%
Bulk Storage subtotal	1.89	7.8%	0.37	7.8%	0.04	7.8%	0.07	7.8%	0.06	7.8%	0.14	7.8%	2.03	7.8%	0.53	7.8%
ΔPS_{FW0}																
Flour Milling	0.21	0.9%	0.04	0.9%	0.00	0.9%	0.01	0.9%	0.01	0.9%	0.02	0.9%	0.22	0.9%	0.06	0.9%
ΔPS_{SW0}																
Stockfeed manufacturing	0.55	2.3%	0.11	2.3%	0.01	2.3%	0.02	2.3%	0.02	2.3%	0.04	2.3%	0.59	2.3%	0.15	2.3%

ΔPS_{Mwo} Malt Manufacturing	0.36	1.5%	0.07	1.5%	0.01	1.5%	0.01	1.5%	0.00	0.4%	0.03	1.5%	0.38	1.5%	0.10	1.5%
ΔPS_{Cwo} Canola Processing	0.03	0.1%	0.01	0.1%	0.00	0.1%	0.00	0.1%	0.00	0.1%	0.00	0.1%	0.03	0.1%	0.01	0.1%
Producer Surplus subtotal:	15.22	62.8%	2.96	62.8%	0.33	62.8%	0.58	62.8%	0.51	62.8%	1.12	62.8%	16.35	62.8%	4.24	62.8%
Overseas Consumers:																
ΔCS_{Zw1} Export Wheat	3.11	12.8%	0.61	12.8%	0.07	12.8%	0.12	12.8%	0.10	12.8%	0.23	12.8%	3.34	12.8%	0.87	12.8%
ΔCS_{Zw2} Export Barley	0.81	3.3%	0.16	3.3%	0.02	3.3%	0.03	3.3%	0.03	3.3%	0.06	3.3%	0.87	3.3%	0.23	3.3%
ΔCS_{Zw3} Export Canola	0.92	3.8%	0.18	3.8%	0.02	3.8%	0.04	3.8%	0.03	3.8%	0.07	3.8%	0.99	3.8%	0.26	3.8%
ΔCS_{Zw4} Export Lupins	0.12	0.5%	0.02	0.5%	0.00	0.5%	0.00	0.5%	0.00	0.5%	0.01	0.5%	0.12	0.5%	0.03	0.5%
ΔCS_{Sw1} Export Stockfeed	0.12	0.5%	0.02	0.5%	0.00	0.5%	0.00	0.5%	0.00	0.5%	0.01	0.5%	0.13	0.5%	0.03	0.5%
ΔCS_{Mw1} Export Malt	0.15	0.6%	0.03	0.6%	0.00	0.6%	0.01	0.6%	0.00	0.6%	0.01	0.6%	0.16	0.6%	0.04	0.6%

ΔCS_{CW2} Export Canola Oil	0.02	0.1%	0.00	0.1%	0.00	0.1%	0.00	0.1%	0.00	0.1%	0.00	0.1%	0.02	0.1%	0.01	0.1%
Overseas consumers subtotal	5.24	21.6%	1.02	21.6%	0.11	21.6%	0.20	21.6%	0.17	21.6%	0.38	21.6%	5.63	21.6%	1.46	21.6%
Domestic consumers:																
ΔCS_{FW1} Domestic Flour	1.18	4.9%	0.23	4.9%	0.03	4.9%	0.04	4.9%	0.04	4.9%	0.09	4.9%	1.27	4.9%	0.33	4.9%
ΔCS_{SW2} Domestic Stockfeed	2.13	8.8%	0.41	8.8%	0.05	8.8%	0.08	8.8%	0.07	8.8%	0.16	8.8%	2.29	8.8%	0.59	8.8%
ΔCS_{MW2} Domestic Malt	0.28	1.2%	0.05	1.2%	0.01	1.2%	0.01	1.2%	0.01	1.2%	0.02	1.2%	0.30	1.2%	0.08	1.2%
ΔCS_{CW3} Domestic Canola Oil	0.18	0.7%	0.03	0.7%	0.00	0.7%	0.01	0.7%	0.01	0.7%	0.01	0.7%	0.19	0.7%	0.05	0.7%
Domestic consumers subtotal	3.77	15.6%	0.73	15.6%	0.08	15.6%	0.14	15.6%	0.13	15.6%	0.28	15.6%	4.05	15.6%	1.05	15.6%
Consumer Surplus Subtotal	9.01	37.2%	1.75	37.2%	0.19	37.2%	0.34	37.2%	0.30	37.2%	0.66	37.2%	9.68	37.2%	2.51	37.2%
Total Economic Surplus	24.23	100.0%	4.72	100.0%	0.52	100.0%	0.92	100.0%	0.80	100.0%	1.78	100.0%	26.03	100.0%	6.75	100.0%

Table 9.4 Experimental results for model validation when all input substitution and output transformation elasticities are set to zero ($\sigma, \tau = 0$), southern region

	Scenario 1 ($t_{Xsv} = -1\%$)		Scenario 2 ($t_{Ys1o} = -1\%$)		Scenario 3 ($t_{Fso} = -1\%$)		Scenario 4 ($t_{Sso} = -1\%$)		Scenario 5 ($n_{Ss1} = 1\%$)		Scenario 6 ($n_{Ss2} = 1\%$)		Scenario 7 ($n_{Zs1} = 1\%$)		Scenario 8 ($n_{Zs2} = 1\%$)	
	\$m	%					\$m	%					\$m	%		
ΔPS_{Xs0}	2.70	14.6%	0.69	14.6%	0.27	14.6%	0.58	14.6%	0.46	14.6%	1.02	14.6%	2.75	14.6%	0.91	14.6%
ΔPS_{Xsv}	1.77	9.6%	0.45	9.6%	0.17	9.6%	0.38	9.6%	0.30	9.6%	0.67	9.6%	1.80	9.6%	0.60	9.6%
Farm subtotal	4.47	24.2%	1.14	24.2%	0.44	24.2%	0.97	24.2%	0.76	24.2%	1.68	24.2%	4.55	24.2%	1.51	24.2%
ΔPS_{Ys1o}																
Bulk Storage for wheat	0.54	2.9%	0.14	2.9%	0.05	2.9%	0.12	2.9%	0.09	2.9%	0.20	2.9%	0.55	2.9%	0.18	2.9%
ΔPS_{Ys2o}																
Bulk Storage for barley	0.29	1.6%	0.07	1.6%	0.03	1.6%	0.06	1.6%	0.05	1.6%	0.11	1.6%	0.30	1.6%	0.10	1.6%
ΔPS_{Ys3o}																
Bulk Storage for canola	0.08	0.4%	0.02	0.4%	0.01	0.4%	0.02	0.4%	0.01	0.4%	0.03	0.4%	0.08	0.4%	0.03	0.4%
ΔPS_{Ys4o}																
Bulk Storage for peas	0.07	0.4%	0.02	0.4%	0.01	0.4%	0.01	0.4%	0.01	0.4%	0.03	0.4%	0.07	0.4%	0.02	0.4%
Bulk Storage subtotal	0.98	5.3%	0.25	5.3%	0.10	5.3%	0.21	5.3%	0.17	5.3%	0.37	5.3%	1.00	5.3%	0.33	5.3%
ΔPS_{Fso}																
Flour Milling	0.35	1.9%	0.09	1.9%	0.03	1.9%	0.08	1.9%	0.06	1.9%	0.13	1.9%	0.36	1.9%	0.12	1.9%
ΔPS_{Sso}																
Stockfeed manufacturing	1.15	6.2%	0.29	6.2%	0.11	6.2%	0.25	6.2%	0.20	6.2%	0.43	6.2%	1.17	6.2%	0.39	6.2%

ΔPS_{MSO} Malt Manufacturing	0.27	1.5%	0.07	1.5%	0.03	1.5%	0.06	1.5%	0.05	1.5%	0.10	1.5%	0.28	1.5%	0.09	1.5%
ΔPS_{CSO} Oilseed Processing and Refining	0.09	0.5%	0.02	0.5%	0.01	0.5%	0.02	0.5%	0.02	0.5%	0.04	0.5%	0.09	0.5%	0.03	0.5%
Southern region Producer Surplus:	7.32	39.6%	1.86	39.6%	0.72	39.6%	1.58	39.6%	1.25	39.6%	2.75	39.6%	7.45	39.6%	2.47	39.6%
ΔPS_{Y5} Northern Region Wheat Supplier	1.62	8.8%	0.41	8.8%	0.16	8.8%	0.35	8.8%	0.28	8.8%	0.61	8.8%	1.65	8.8%	0.55	8.8%
ΔPS_{Y6} Northern Region Barley Supplier	0.28	1.5%	0.07	1.5%	0.03	1.5%	0.06	1.5%	0.05	1.5%	0.11	1.5%	0.29	1.5%	0.09	1.5%
ΔPS_{Y7} Northern Region Canola Supplier	0.57	3.1%	0.14	3.1%	0.06	3.1%	0.12	3.1%	0.10	3.1%	0.21	3.1%	0.58	3.1%	0.19	3.1%
Northern region Producer Surplus	2.47	13.4%	0.63	13.4%	0.24	13.4%	0.53	13.4%	0.42	13.4%	0.93	13.4%	2.51	13.4%	0.83	13.4%
Total Producer Surplus:	9.79	52.9%	2.49	52.9%	0.97	52.9%	2.11	52.9%	1.67	52.9%	3.68	52.9%	9.96	52.9%	3.30	52.9%
Overseas consumers:																
ΔCS_{ZS1} Wheat	1.08	5.8%	0.27	5.8%	0.11	5.8%	0.23	5.8%	0.18	5.8%	0.41	5.8%	1.10	5.8%	0.36	5.8%

ΔCS_{Zs2} Barley	0.36	1.9%	0.09	1.9%	0.04	1.9%	0.08	1.9%	0.06	1.9%	0.14	1.9%	0.37	1.9%	0.12	1.9%
ΔCS_{Zs3} Canola	0.28	1.5%	0.07	1.5%	0.03	1.5%	0.06	1.5%	0.05	1.5%	0.11	1.5%	0.29	1.5%	0.09	1.5%
ΔCS_{Zs4} Peas	0.02	0.1%	0.01	0.1%	0.00	0.1%	0.01	0.1%	0.00	0.1%	0.01	0.1%	0.03	0.1%	0.01	0.1%
ΔCS_{Ss1} Stockfeed	0.23	1.2%	0.06	1.2%	0.02	1.2%	0.05	1.2%	0.04	1.2%	0.09	1.2%	0.23	1.2%	0.08	1.2%
ΔCS_{Ms1} Malt	0.12	0.6%	0.03	0.6%	0.01	0.6%	0.03	0.6%	0.02	0.6%	0.04	0.6%	0.12	0.6%	0.04	0.6%
ΔCS_{Cs2} Canola Oil	0.06	0.3%	0.01	0.3%	0.01	0.3%	0.01	0.3%	0.01	0.3%	0.02	0.3%	0.06	0.3%	0.02	0.3%
Overseas consumers subtotal	2.15	11.6%	0.54	11.6%	0.21	11.6%	0.46	11.6%	0.37	11.6%	0.81	11.6%	2.18	11.6%	0.72	11.6%
Domestic consumers:																
ΔCS_{Fs1} Domestic Flour	1.84	9.9%	0.47	9.9%	0.18	9.9%	0.40	9.9%	0.31	9.9%	0.69	9.9%	1.87	9.9%	0.62	9.9%
ΔCS_{Ss2} Stockfeed Domestic	4.00	21.6%	1.02	21.6%	0.40	21.6%	0.86	21.6%	0.68	21.6%	1.51	21.6%	4.07	21.6%	1.35	21.6%
ΔCS_{Ms2} Malt Domestic	0.23	1.2%	0.06	1.2%	0.02	1.2%	0.05	1.2%	0.04	1.2%	0.09	1.2%	0.23	1.2%	0.08	1.2%
ΔCS_{Cs3}	0.49	2.7%	0.13	2.7%	0.05	2.7%	0.11	2.7%	0.08	2.7%	0.19	2.7%	0.50	2.7%	0.17	2.7%

Canola Oil Domestic																
Domestic Consumers Subtotal	6.56	35.5%	1.67	35.5%	0.65	35.5%	1.42	35.5%	1.12	35.5%	2.47	35.5%	6.68	35.5%	2.21	35.5%
Total Consumer Surplus	8.71	47.1%	2.21	47.1%	0.86	47.1%	1.88	47.1%	1.48	47.1%	3.28	47.1%	8.86	47.1%	2.94	47.1%
Total Economic Surplus	18.50	100.0%	4.70	100.0%	1.83	100.0%	4.00	100.0%	3.15	100.0%	6.96	100.0%	18.82	100.0%	6.26	100.0%

Table 9.5 Experimental results for model validation when all input substitution and output transformation elasticities are set to zero ($\sigma, \tau = 0$), northern region

	Scenario 1 ($t_{Xnv} = -1\%$)		Scenario 2 ($t_{Yn1o} = -1\%$)		Scenario 3 ($t_{Fno} = -1\%$)		Scenario 4 ($t_{Sno} = -1\%$)		Scenario 5 ($n_{Sn1} = 1\%$)		Scenario 6 ($n_{Sn2} = 1\%$)		Scenario 7 ($n_{Zn1} = 1\%$)		Scenario 8 ($n_{Zn2} = 1\%$)	
	\$m	%	\$m	%	\$m	%	\$m	%					\$m	%		
ΔPS_{Xno}	2.52	12.7%	0.40	12.7%	0.61	12.7%	0.62	12.7%	0.53	12.7%	1.16	12.7%	1.24	12.7%	0.10	12.7%
ΔPS_{Xnv}	1.65	8.3%	0.26	8.3%	0.40	8.3%	0.41	8.3%	0.34	8.3%	0.76	8.3%	0.81	8.3%	0.06	8.3%
Farm subtotal	4.17	21.0%	0.67	21.0%	1.01	21.0%	1.02	21.0%	0.87	21.0%	1.92	21.0%	2.06	21.0%	0.16	21.0%
ΔPS_{Yn1o}																
Storage for wheat	0.32	1.6%	0.05	1.6%	0.08	1.6%	0.08	1.6%	0.07	1.6%	0.15	1.6%	0.16	1.6%	0.01	1.6%
ΔPS_{Yn2o}																
Storage for barley	0.08	0.4%	0.01	0.4%	0.02	0.4%	0.02	0.4%	0.02	0.4%	0.04	0.4%	0.04	0.4%	0.00	0.4%
ΔPS_{Yn3o}																
Storage for canola	0.05	0.3%	0.01	0.3%	0.01	0.3%	0.01	0.3%	0.01	0.3%	0.02	0.3%	0.03	0.3%	0.00	0.3%
ΔPS_{Yn4o}																
Storage for chickpeas	0.03	0.2%	0.00	0.2%	0.01	0.2%	0.01	0.2%	0.01	0.2%	0.01	0.2%	0.02	0.2%	0.00	0.2%
Bulk Storage subtotal	0.48	2.4%	0.08	2.4%	0.12	2.4%	0.12	2.4%	0.10	2.4%	0.22	2.4%	0.24	2.4%	0.02	2.4%
ΔPS_{Fno}																
Flour Milling	0.80	4.0%	0.13	4.0%	0.19	4.0%	0.20	4.0%	0.17	4.0%	0.37	4.0%	0.40	4.0%	0.03	4.0%
ΔPS_{Sno}																
Stockfeed manufacturing	1.22	6.2%	0.20	6.2%	0.30	6.2%	0.30	6.2%	0.26	6.2%	0.56	6.2%	0.60	6.2%	0.05	6.2%

ΔPS_{Mno} Malt Manufacturing	0.12	0.6%	0.02	0.6%	0.03	0.6%	0.03	0.6%	0.02	0.6%	0.05	0.6%	0.06	0.6%	0.00	0.6%
ΔPS_{Cno} Oilseed Processing and Refining	0.09	0.5%	0.01	0.5%	0.02	0.5%	0.02	0.5%	0.02	0.5%	0.04	0.5%	0.05	0.5%	0.00	0.5%
Producer Surplus subtotal:	7.38	34.7%	1.18	34.7%	1.78	34.7%	1.81	34.7%	1.54	34.7%	3.39	34.7%	3.63	34.7%	0.29	34.7%
Overseas consumers:																
ΔCS_{Zn1} Wheat Export	0.49	2.5%	0.08	2.5%	0.12	2.5%	0.12	2.5%	0.10	2.5%	0.23	2.5%	0.24	2.5%	0.02	2.5%
ΔCS_{Zn2} Barley Export	0.04	0.2%	0.01	0.2%	0.01	0.2%	0.01	0.2%	0.01	0.2%	0.02	0.2%	0.02	0.2%	0.00	0.2%
ΔCS_{Zn3} Canola Export	0.09	0.5%	0.01	0.5%	0.02	0.5%	0.02	0.5%	0.02	0.5%	0.04	0.5%	0.05	0.5%	0.00	0.5%
ΔCS_{Zn4} Chickpeas Export	0.16	0.8%	0.03	0.8%	0.04	0.8%	0.04	0.8%	0.03	0.8%	0.07	0.8%	0.08	0.8%	0.01	0.8%
ΔCS_{Sn1} Stockfeed Export	0.26	1.3%	0.04	1.3%	0.06	1.3%	0.06	1.3%	0.05	1.3%	0.12	1.3%	0.13	1.3%	0.01	1.3%
ΔCS_{Mn1} Malt Export	0.05	0.3%	0.01	0.3%	0.01	0.3%	0.01	0.3%	0.01	0.3%	0.02	0.3%	0.03	0.3%	0.00	0.3%

ΔCS_{Cn2} Canola Oil Export	0.06	0.3%	0.01	0.3%	0.01	0.3%	0.01	0.3%	0.01	0.3%	0.03	0.3%	0.03	0.3%	0.00	0.3%
Overseas consumers subtotal	1.16	5.8%	0.18	5.8%	0.28	5.8%	0.28	5.8%	0.24	5.8%	0.53	5.8%	0.57	5.8%	0.05	5.8%
ΔCS_{Fn1} Domestic Flour	4.51	22.7%	0.72	22.7%	1.09	22.7%	1.11	22.7%	0.94	22.7%	2.07	22.7%	2.22	22.7%	0.18	22.7%
ΔCS_{Sn2} Domestic Stockfeed	4.53	22.8%	0.72	22.8%	1.10	22.8%	1.11	22.8%	0.95	22.8%	2.08	22.8%	2.23	22.8%	0.18	22.8%
ΔCS_{Mn2} Domestic Malt	0.10	0.5%	0.02	0.5%	0.02	0.5%	0.03	0.5%	0.02	0.5%	0.05	0.5%	0.05	0.5%	0.00	0.5%
ΔCS_{Cn3} Domestic Canola Oil	0.52	2.6%	0.08	2.6%	0.13	2.6%	0.13	2.6%	0.11	2.6%	0.24	2.6%	0.25	2.6%	0.02	2.6%
Northern Region domestic consumers Subtotal	9.66	48.6%	1.54	48.6%	2.34	48.6%	2.37	48.6%	2.01	48.6%	4.44	48.6%	4.76	48.6%	0.38	48.6%
ΔCS_{Zn11} Wheat to Southern Region	1.41	7.1%	0.23	7.1%	0.34	7.1%	0.35	7.1%	0.29	7.1%	0.65	7.1%	0.70	7.1%	0.06	7.1%
ΔCS_{Zn12} Barley to Southern Region	0.24	1.2%	0.04	1.2%	0.06	1.2%	0.06	1.2%	0.05	1.2%	0.11	1.2%	0.12	1.2%	0.01	1.2%

ΔCS_{Zn13} Canola to Southern Region	0.49	2.5%	0.08	2.5%	0.12	2.5%	0.12	2.5%	0.10	2.5%	0.23	2.5%	0.24	2.5%	0.02	2.5%
Southern Region Consumer Surplus Subtotal	2.15	10.8%	0.34	10.8%	0.52	10.8%	0.53	10.8%	0.45	10.8%	0.99	10.8%	1.06	10.8%	0.08	10.8%
Total Consumer Surplus	12.97	65.3%	2.07	65.3%	3.13	65.3%	3.18	65.3%	2.70	65.3%	5.96	65.3%	6.39	65.3%	0.51	65.3%
Total Economic Surplus	19.86	100.0%	3.17	100.0%	4.80	100.0%	4.88	100.0%	4.14	100.0%	9.12	100.0%	9.78	100.0%	0.78	100.0%

9.3 Stochastic Sensitivity Analysis

Discrete sensitivity analysis is a simple common approach in treating uncertainty in parameter values and their impacts on the modelling results. When the number of uncertain parameters is numerous, it becomes impractical and cumbersome to attempt to examine the sensitivity impacts of all these parameters individually. This is certainly the case for the models presented in this study, for as can be observed in Tables 6.2 to 6.4 in Section 6.3, there are a large number of price elasticities associated with each of the three regional EDMs. Moreover, little inference can be made around the 'true value' of the uncertain parameters using a discrete method.

Zhao *et al.* (1999) presented a robust approach used in treating uncertainty in parameter values, namely stochastic sensitivity analysis. This approach involves assigning subjective probability distributions to each of the uncertain elasticity values. The subsequent surplus change results generated will then also be in the form of probability distributions, where confidence intervals can be used in interpreting the results. This section applies this stochastic sensitivity analysis approach for the uncertain elasticity values used in the grains EDMs developed in this study.

In Tables 9.6, 9.7 and 9.8, the subjective probability distributions assigned to each elasticity value for each region are shown. Alongside the specified probability distributions are the implied 95 per cent probability confidence intervals for that parameter.

Correlations between the export demand elasticities of grains are also factored in due to the interrelation of price movements in grains. For example, high price correlations between wheat and barley indicates that the export demand elasticity of wheat would also be highly correlated with the export demand elasticity of barley. Tables 9.9, 9.10 and 9.11 provide the correlation matrices of export demand elasticities for each of the three regions. Off-diagonal values in the matrices were calculated using annual historical data from ABARES (2019b).

Most elasticities are assumed to be normally distributed and restricted to be either negative or positive by truncation. All uncertain elasticity values are allowed to change according to their probability distributions specified in these tables. Monte Carlo random sampling was performed using these specifications with @Risk computer software. The random sampling was conducted 2,000 times for each research scenario, with each scenario using different combinations of parameter values. Such a large sample size enables a high level of precision relating to a specified

distribution. This generates 2,000 sets of price and quantity changes and subsequently 2,000 sets of surplus change results for each scenario.

Table 9.6 Subjective probability distributions and 95% confidence Intervals for market elasticities, western region

	Demand Elasticities	Supply Elasticities	Input Substitution Elasticities	Product Transformation Elasticities
Farm		$\varepsilon_{Xwv,wwv} \sim N(3.0, 0.5^2 > 0), (2.02, 3.98)$ $\varepsilon_{Xw0,ww0} \sim N(1.0, 0.25^2 > 0), (0.51, 1.49)$	$\sigma_{Xwv,Xw0} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Yw1,Yw2} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Yw1,Yw3} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Yw1,Yw4} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Yw2,Yw3} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Yw2,Yw4} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Yw3,Yw4} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$
Wheat Storage	$\eta_{Zw1,uw1} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$	$\varepsilon_{Yw10,vw10} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$	$\sigma_{Yw1,Yw10} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zw1,Zw5} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Zw1,Zw6} \sim N(-0.5, 0.1^2 \leq 0), (-0.70, -0.30)$ $\tau_{Zw5,Zw6} \sim N(-0.5, 0.1^2 \leq 0), (-0.70, -0.30)$
Barley Storage	$\eta_{Zw2,uw2} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$	$\varepsilon_{Yw20,vw20} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$	$\sigma_{Yw2,Yw20} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zw2,Zw7} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$ $\tau_{Zw2,Zw8} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$ $\tau_{Zw7,Zw8} \sim N(-0.5, 0.1^2 \leq 0), (-0.70, -0.30)$
Canola Storage	$\eta_{Zw3,uw2} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$	$\varepsilon_{Yw30,vw30} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$	$\sigma_{Yw3,Yw30} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zw3,Zw9} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$
Lupin Storage	$\eta_{Zw4,uw2} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$	$\varepsilon_{Yw40,vw40} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$	$\sigma_{Yw4,Yw40} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zw4,Zw10} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$
Flour Milling	$\eta_{Fw1,gw1} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Fw0,gw0} \sim N(1.5, 0.25^2 > 0), (1.01, 1.99)$	$\sigma_{Zw5,Fw0} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Fw1,Fw2} \sim N(-0.01, 0.01^2 \leq 0), (-0.30, -0.00)$

Stockfeed Manufacturing	$\eta_{Sw1,tw1} \sim N(-4.0, 1.0^2 < 0), (-5.96, -2.04)$ $\eta_{Sw2,tw2} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Swo,two} \sim N(1.0, 0.25^2 > 0), (0.51, 1.49)$	$\sigma_{Zw6,Zw7} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zw6,Fw2} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zw6,Zw10} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zw6,Cw1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zw6,Swo} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Zw7,Fw2} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zw7,Cw1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zw7,Zw10} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zw7,Swo} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Zw10,Cw1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zw10,Fw2} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zw10,Swo} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Fw2,Cw1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Fw2,Swo} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Cw1,Swo} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$	$\tau_{Sw1,Sw2} \sim N(-2.0, 0.5^2 \leq 0), (-0.30, -1.02)$
Malt Manufacturing	$\eta_{Mw1,nw1} \sim N(-4.0, 1.0^2 < 0), (-5.96, -2.04)$ $\eta_{Mw2,nw2} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Mwo,nwo} \sim N(1.0, 0.25^2 > 0), (0.51, 1.49)$	$\sigma_{Zw8,Mwo} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Mw1,Mw2} \sim N(-2.0, 0.5^2 \leq 0), (-0.30, -1.02)$
Oilseed Crushing and Refining	$\eta_{Cw2,dw2} \sim N(-4.0, 1.0^2 < 0), (-5.96, -2.04)$ $\eta_{Cw3,dw3} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Cwo,dwo} \sim N(1.0, 0.25^2 > 0), (0.51, 1.49)$	$\sigma_{Zw9,Cwo} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Cw1,Cw2} \sim N(-0.01, 0.01^2 \leq 0), (-0.30, -0.00)$ $\tau_{Cw1,Cw3} \sim N(-0.01, 0.01^2 \leq 0), (-0.30, -0.00)$ $\tau_{Cw2,Cw3} \sim N(-2.0, 0.5^2 \leq 0), (-0.30, -1.02)$

Table 9.7 Subjective probability distributions and 95% confidence Intervals for market elasticities, southern region

	Demand Elasticities	Supply Elasticities	Input Substitution Elasticities	Product Transformation Elasticities
Farm		$\varepsilon_{XSV,WSV} \sim N(3.0, 0.5^2 > 0), (2.02, 3.98)$ $\varepsilon_{XSO,WSO} \sim N(1.0, 0.25^2 > 0), (0.51, 1.49)$	$\sigma_{XSV,XSO} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Ys1,Ys2} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Ys1,Ys3} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Ys1,Ys4} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Ys2,Ys3} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Ys2,Ys4} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Ys3,Ys4} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$
Wheat Storage	$\eta_{Zs1,us1} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$	$\varepsilon_{Ys10,vs10} \sim N(2.5, 1.0^2 > 0), (1.52, 3.48)$ $\varepsilon_{Ys5,vs5} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$	$\sigma_{Ys1,Ys10} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$ $\sigma_{Ys1,Ys5} \sim N(2.0, 0.5^2 \geq 0), (1.02, 2.98)$ $\sigma_{Ys5,Ys10} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zs1,Zs5} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Zs1,Zs6} \sim N(-0.5, 0.1^2 \leq 0), (-0.70, -0.30)$ $\tau_{Zs5,Zs6} \sim N(-0.5, 0.1^2 \leq 0), (-0.70, -0.30)$
Barley Storage	$\eta_{Zs2,us2} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$	$\varepsilon_{Ys20,vs20} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$ $\varepsilon_{Ys6,vs6} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$	$\sigma_{Ys2,Ys20} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$ $\sigma_{Ys2,Ys6} \sim N(2.0, 0.5^2 \geq 0), (1.02, 2.98)$ $\sigma_{Ys6,Ys20} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zs2,Zs7} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$ $\tau_{Zs2,Zs8} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$ $\tau_{Zs7,Zs8} \sim N(-0.5, 0.1^2 \leq 0), (-0.70, -0.30)$
Canola Storage	$\eta_{Zs3,us2} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$	$\varepsilon_{Ys30,vs30} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$ $\varepsilon_{Ys7,vs7} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$	$\sigma_{Ys3,Ys30} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$ $\sigma_{Ys3,Ys7} \sim N(2.0, 0.5^2 \geq 0), (1.02, 2.98)$ $\sigma_{Ys7,Ys30} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zs3,Zs9} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$
Lupin Storage	$\eta_{Zs4,us2} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$	$\varepsilon_{Ys40,vs40} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$	$\sigma_{Ys4,Ys40} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zs4,Zs10} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$
Flour Milling	$\eta_{Fs1,gs1} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Fs0,gs0} \sim N(1.5, 0.5^2 > 0), (1.01, 1.99)$	$\sigma_{Zs5,Fs0} \sim N(0.5, 0.1^2 \geq 0), (0.30, 0.70)$	$\tau_{Fs1,Fs2} \sim N(-0.01, 0.01^2 \leq 0), (-0.30, -0.00)$
Stockfeed Manufacturing	$\eta_{Ss1,ts1} \sim N(-4.0, 1.0^2 < 0), (-5.96, -2.04)$ $\eta_{Ss2,ts2} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Ss0,tso} \sim N(1.0, 0.5^2 > 0), (0.51, 1.49)$	$\sigma_{Zs6,Zs7} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zs6,Fs2} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zs6,Zs10} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zs6,Cs1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zs6,Ss0} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$	$\tau_{Ss1,Ss2} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$

			$\sigma_{Zs7, Fs2} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zs7, Cs1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zs7, Zs10} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zs7, Sso} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Zs10, Cs1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zs10, Fs2} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zs10, Sso} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Fs2, Cs1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Fs2, Sso} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Cs1, Sso} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$	
Malt Manufacturing	$\eta_{Ms1, ns1} \sim N(-4.0, 1.0^2 < 0), (-5.96, -2.04)$ $\eta_{Ms2, ns2} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\epsilon_{Mso, nso} \sim N(1.0, 0.5^2 > 0), (0.51, 1.49)$	$\sigma_{Zs8, Mso} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Ms1, Ms2} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$
Oilseed Crushing and Refining	$\eta_{Cs2, ds2} \sim N(-4.0, 1.0^2 < 0), (-5.96, -2.04)$ $\eta_{Cs3, ds3} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\epsilon_{Cso, dso} \sim N(1.0, 0.5^2 > 0), (0.51, 1.49)$	$\sigma_{Zs9, Cso} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Cs1, Cs2} \sim N(-0.01, 0.01^2 \leq 0), (-0.30, -0.00)$ $\tau_{Cs1, Cs3} \sim N(-0.01, 0.01^2 \leq 0), (-0.30, -0.00)$ $\tau_{Cs2, Cs3} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$

Table 9.8 Subjective probability distributions and 95% confidence Intervals for market elasticities, northern region

	Demand Elasticities	Supply Elasticities	Input Substitution Elasticities	Product Transformation Elasticities
Farm		$\varepsilon_{Xnv,wnv} \sim N(3.0, 0.5^2 > 0), (2.02, 3.98)$ $\varepsilon_{Xno,wno} \sim N(1.0, 0.5^2 > 0), (0.51, 1.49)$	$\sigma_{Xnv,Xno} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Yn1,Yn2} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Yn1,Yn3} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Yn1,Yn4} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Yn2,Yn3} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Yn2,Yn4} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Yn3,Yn4} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$
Wheat Storage	$\eta_{Zn1,un1} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$ $\eta_{Zn11,un11} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Yn10,vn10} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$	$\sigma_{Yn1,Yn10} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zn1,Zn5} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Zn1,Zn6} \sim N(-0.5, 0.1^2 \leq 0), (-0.70, -0.30)$ $\tau_{Zn1,Zn11} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$ $\tau_{Zn5,Zn6} \sim N(-0.5, 0.1^2 \leq 0), (-0.70, -0.30)$ $\tau_{Zn5,Zn11} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$ $\tau_{Zn6,Zn11} \sim N(-0.5, 0.1^2 \leq 0), (-0.70, -0.30)$
Barley Storage	$\eta_{Zn2,un2} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$ $\eta_{Zn12,un12} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Yn20,vn20} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$	$\sigma_{Yn2,Yn20} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zn2,Zn7} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$ $\tau_{Zn2,Zn8} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$ $\tau_{Zn2,Zn12} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Zn7,Zn8} \sim N(-0.5, 0.1^2 \leq 0), (-0.70, -0.30)$ $\tau_{Zn7,Zn12} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Zn8,Zn12} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$
Canola Storage	$\eta_{Zn3,un2} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$ $\eta_{Zn13,un13} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Yn30,vn30} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$	$\sigma_{Yn3,Yn30} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zn3,Zn9} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Zn3,Zn13} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$ $\tau_{Zn9,Zn13} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$
Lupin Storage	$\eta_{Zn4,un2} \sim N(-5.0, 1.0^2 < 0), (-6.96, -3.04)$	$\varepsilon_{Yn40,vn40} \sim N(2.5, 0.5^2 > 0), (1.52, 3.48)$	$\sigma_{Yn4,Yn40} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Zn4,Zn10} \sim N(-3.0, 0.5^2 \leq 0), (-3.98, -2.02)$
Flour Milling	$\eta_{Fn1,gn1} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Fn0,gn0} \sim N(1.5, 0.5^2 > 0), (1.01, 1.99)$	$\sigma_{Zn5,Fn0} \sim N(0.5, 0.1^2 \geq 0), (0.30, 0.70)$	$\tau_{Fn1,Fn2} \sim N(-0.01, 0.01^2 \leq 0), (-0.30, -0.00)$

Stockfeed Manufacturing	$\eta_{Sn1,tn1} \sim N(-4.0, 1.0^2 < 0), (-5.96, -2.04)$ $\eta_{Sn2,tn2} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Sno,tno} \sim N(1.0, 0.5^2 > 0), (0.51, 1.49)$	$\sigma_{Zn6,Zn7} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zn6,Fn2} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zn6,Zn10} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zn6,Cn1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zn6,Sno} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Zn7,Fn2} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zn7,Cn1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zn7,Zn10} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zn7,Sno} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Zn10,Cn1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zn10,Fn2} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Zn10,Sno} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Fn2,Cn1} \sim N(0.5, 0.1^2 > 0), (0.30, 0.70)$ $\sigma_{Fn2,Sno} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$ $\sigma_{Cn1,Sno} \sim N(0.1, 0.1^2 > 0), (0.01, 0.30)$	$\tau_{Sn1,Sn2} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$
Malt Manufacturing	$\eta_{Mn1,nn1} \sim N(-4.0, 1.0^2 < 0), (-5.96, -2.04)$ $\eta_{Mn2,nn2} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Mno,tno} \sim N(1.0, 0.5^2 > 0), (0.51, 1.49)$	$\sigma_{Zn8,Mno} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Mn1,Mn2} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$
Oilseed Crushing and Refining	$\eta_{Cn2,dn2} \sim N(-4.0, 1.0^2 < 0), (-5.96, -2.04)$ $\eta_{Cn3,dn3} \sim N(-0.5, 0.1^2 < 0), (-0.70, -0.30)$	$\varepsilon_{Cno,dno} \sim N(1.0, 0.5^2 > 0), (0.51, 1.49)$	$\sigma_{Zn9,Cno} \sim N(0.1, 0.1^2 \geq 0), (0.01, 0.30)$	$\tau_{Cn1,Cn2} \sim N(-0.01, 0.01^2 \leq 0), (-0.30, -0.00)$ $\tau_{Cn1,Cn3} \sim N(-0.01, 0.01^2 \leq 0), (-0.30, -0.00)$ $\tau_{Cn2,Cn3} \sim N(-2.0, 0.5^2 \leq 0), (-2.98, -1.02)$

Table 9.9 Correlation matrix for export demand elasticities, western region

	$\eta_{Zw1,uw1}$	$\eta_{Zw2,uw2}$	$\eta_{Zw3,uw3}$	$\eta_{Zw4,uw4}$
$\eta_{Zw1,uw1}$	1	0.93	0.80	0.75
$\eta_{Zw2,uw2}$	0.93	1	0.80	0.68
$\eta_{Zw3,uw3}$	0.80	0.80	1	0.74
$\eta_{Zw4,uw4}$	0.75	0.68	0.74	1

Source: ABARES Agricultural Commodities (2019b), Gross unit values of farm production, 1989-90 to 2019-20

Table 9.10 Correlation matrix for export demand elasticities, southern region

	$\eta_{Zs1,us1}$	$\eta_{Zs2,us2}$	$\eta_{Zs3,us3}$	$\eta_{Zs4,us4}$
$\eta_{Zs1,us1}$	1	0.93	0.80	0.82
$\eta_{Zs2,us2}$	0.93	1	0.80	0.86
$\eta_{Zs3,us3}$	0.80	0.80	1	0.79
$\eta_{Zs4,us4}$	0.82	0.86	0.79	1

Source: ABARES Agricultural Commodities (2019b), Gross unit values of farm production, 1989-90 to 2019-20

Table 9.11 Correlation matrix for export demand elasticities, northern region

	$\eta_{Zn1,un1}$	$\eta_{Zn2,un2}$	$\eta_{Zn3,un3}$	$\eta_{Zn4,un4}$
$\eta_{Zs1,us1}$	1	0.93	0.80	0.61
$\eta_{Zn2,un2}$	0.93	1	0.80	0.68
$\eta_{Zn3,un3}$	0.80	0.80	1	0.70
$\eta_{Zn4,un4}$	0.61	0.68	0.70	1

Source: ABARES Agricultural Commodities (2019b), Gross unit values of farm production, 1989-90 to 2019-20

9.3.1 Summary Statistics for the Economic Surplus Changes

From the probability distributions specified in tables 9.6, 9.7 and 9.8, 2,000 values are randomly drawn for each parameter value, which results in 2,000 sets of price and quantity changes, along with 2,000 sets of economic surplus changes. This process is repeated for each scenario in each of the three regional EDMs.

Summary statistics for the economic surplus changes to Scenarios 1, 2, 5, 7 and 8 for each region are reported in Tables 9.9, 9.10 and 9.11. Particular attention is placed on these scenarios as they observably generate the greatest share of benefits to farm production in each region in the base results (>30% of benefits accrued) as presented in Table 8.4. Their percentage share rankings are directly comparable without the requirement of information on their investment costs. Stochastic sensitivity analysis can be applied to test the robustness of the rankings obtained in the base simulation.

For each scenario examined, the figures on the left side column provide the benefits in millions of dollars and the figures on the right side column represent the percentage share of the total accruing to each industry group. For each industry group, the point estimates obtained from the base simulation results in Chapter 7 are reported, along with means, standard deviation and 95% probability intervals obtained from the simulation.

Table 9.12 Summary statistics for stochastic sensitivity analysis, western region

	Scenario 1 ($t_{xwv} = -1\%$)		Scenario 2 ($t_{yw10} = -1\%$)		Scenario 5 ($n_{sw1} = 1\%$)		Scenario 7 ($n_{zw1} = 1\%$)		Scenario 8 ($n_{zw2} = 1\%$)	
	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%
Farm Production										
Base	14.4	59.4	2.64	56.0	0.35	43.3	16.01	61.4	3.59	53.1
Mean	14.38	59.4	2.59	54.8	0.34	42.6	15.98	61.31	3.58	52.9
Standard Deviation	1.13	4.7	0.29	6.19	0.05	0.06	1.52	5.84	0.39	5.83
95% PI	(12.24, 16.67)	(50.49, 68.81)	(2.00, 3.14)	(42.4, 66.4)	(0.25, 0.44)	(41.7, 75.8)	(13.05, 19.00)	(50.04, 72.94)	(2.81, 4.37)	(41.4, 64.5)
Wheat Storage										
Base	1.31	5.4	0.63	13.4	0.04	4.6	2.74	10.5	-0.1	-1.4
Mean	1.3	5.4	0.68	14.5	0.04	4.6	2.7840	10.7	-0.1	-1.47
Standard Deviation	0.3	1.2	0.17	3.54	0.01	1.18	0.59	2.26	0.05	0.69
95% PI	(0.83, 2.03)	(3.42, 8.37)	(0.43, 1.07)	(9.02, 22.71)	(0.02, 0.06)	(2.69, 7.35)	(1.91, 4.20)	(7.33, 16.11)	(-0.21, -0.02)	(-3.03, -0.34)
Barley Storage										
Base	0.50	2.1	-0.03	-0.6%	0.01	1.3	-0.16	-0.6	1.33	19.6
Mean	0.49	2.03	-0.03	-0.6	0.01	1.4	-0.16	-0.6%	1.34	19.8
Standard Deviation	0.11	0.45	0.01	0.29	0.003	0.41	0.08	0.32	0.25	3.74
95% PI	(0.36, 0.73)	(1.33, 3.02)	(-0.06, 0.00)	(-1.19, -0.09)	(0.01, 0.02)	(0.74, 2.37)	(-0.35, -0.03)	(-1.34, -0.10)	(0.94, 1.94)	(13.86, 28.65)
Canola Storage										
Base	0.25	1.0	-0.01	-0.3%	0.00	0.0%	-0.08	-0.3%	-0.02	-0.3

Mean	0.25	1.0	-0.01	-0.3	0.00	0.0%	-0.09	-0.33	-0.02	-0.29
Standard Deviation	0.06	0.25	0.00	0.14	0.00	0.09	0.04	0.16	0.01	0.17
95% PI	(0.16, 0.40)	(0.64, 1.66)	(-0.03, 0.00)	(-0.62, -0.06)	(0.00, 0.00)	(-0.2, 0.16)	(-0.18, -0.02)	(-0.62, -0.1)	(-0.04, -0.00)	(-0.58, -0.05)
Lupin Storage										
Base	0.05	0.2	0.00	0.0	0.01	1.1	-0.01	-0.1	0.00	-0.1
Mean	0.05	0.2	0.00	0.0	0.01	1.16	-0.01	-0.05	-0.00	-0.05
Standard Deviation	0.01	0.05	0.001	0.03	0.002	0.27	0.01	0.03	0.00	0.03
95% PI	(0.03, 0.08)	(0.13, 0.31)	(0.00, 0.00)	(-0.10, 0.01)	(0.01, 0.01)	(0.73, 1.76)	(-0.03, 0.00)	(-0.13, 0.00)	(-0.01, 0.00)	(-0.12, 0.00)
Flour Milling										
Base	0.03	0.1	0.01	0.2	0.02	2.1	-0.01	0.0	0.00	0.0
Mean	0.03	0.1	0.01	0.2	0.02	2.06	-0.01	-0.02	-0.00	-0.02
Standard Deviation	0.01	0.03	0.003	0.06	0.003	0.49	0.01	0.03	0.00	0.02
95% PI	(0.01, 0.04)	(0.04, 0.18)	(0.00, 0.01)	(0.07, 0.29)	(0.01, 0.02)	(1.20, 3.10)	(-0.02, 0.01)	(-0.08, 0.03)	(-0.00, -0.00)	(-0.06, -0.00)
Stockfeed manufacturing										
Base	0.21	0.9	0.01	0.9	0.26	32.4	0.16	0.6	0.00	-0.1
Mean	0.20	0.8	0.04	0.9	0.26719	33.14	0.15	0.58	-0.00	-0.05
Standard Deviation	0.06	0.24	0.01	0.28	0.06355	7.88	0.06	0.22	0.01	0.18
95% PI	(0.115, 0.339)	(0.48, 1.40)	(0.02, 0.07)	(0.50, 1.55)	(0.17, 0.42)	(21.2, 52.2)	(0.06, 0.29)	(0.23, 1.1)	(-0.03, 0.03)	(-0.37, 0.38)
Malt Manufacturing										

Base	0.11	0.5	-0.01	-0.1	0.00	0.1	-0.04	-0.1	0.05	0.7
Mean	0.11	0.5	-0.01	-0.1	0.00	0.14	-0.04	-0.14	0.049	0.73
Standard Deviation	0.03	0.10	0.003	0.07	0.00	0.12	0.02	0.07	0.048	0.71
95% PI	(0.07, 0.17)	(0.28, 0.69)	(-0.01, 0.00)	(-0.28, -0.02)	(0.00, 0.00)	(0.03, 0.42)	(-0.08, -0.02)	(-0.30, -0.02)	(-0.02, 0.17)	(-0.32, 2.47)
Canola Processing										
Base	0.01	0.0	0.00	0.0%	0.01	0.8	0.00	0.0	0.00	0.0
Mean	0.01	0.0	0.00	0.0	0.01	0.75	-0.002	0.0	-0.00	-0.01
Standard Deviation	0.003	0.02	0.00	0.0	0.001	0.24	0.002	0.00	0.00	0.00
95% PI	(0.01, 0.02)	(0.02, 0.08)	(0.00, 0.00)	(-0.02, 0.01)	(0.00, 0.01)	(0.45, 1.28)	(-0.01, 0.00)	(-0.02, 0.00)	(-0.00, 0.00)	(-0.03, 0.00)
Overseas Consumers										
Base	6.52	26.9	1.25	26.6	0.28	34.3	7.10	27.2	1.94	28.7
Mean	6.56	27.1	1.26	26.7	0.28	34.75	7.1	27.3	1.94	28.63
Standard Deviation	0.9328	3.85%	0.25	5.35	0.05	6.386%	1.43	5.50	0.40	5.94
95% PI	(4.84, 8.49)	(19.98, 35.05)	(0.82, 1.82)	(17.4, 38.6)	(0.19, 0.39)	(24.0, 48.7)	(4.64, 10.25)	(17.80, 39.30)	(1.21, 2.81)	(17.8, 41.5)
Domestic Consumers										
Base	0.85	3.5	0.19	3.9	-0.16	-20.2	0.36	1.4	-0.01	-0.2
Mean	0.84	3.5	0.18	3.9	-0.17	-20.63	0.35	1.32	-0.01	-0.15
Standard Deviation	0.10	0.42	0.02	0.50	0.07	9.15	0.14	0.54	0.04	0.58
95% PI	(0.64, 1.03)	(2.65, 4.25)	(0.14, 0.23)	(2.93, 4.89)	(-0.31, -0.02)	(-38.9, -2.5)	(0.09, 0.64)	(0.34, 2.44)	(-0.08, 0.07)	(-1.18, 1.07)
Total Economic Surplus										

Base	24.23	100.0%	4.72	100.0%	0.81	100.0%	26.07	100.0%	6.77	100.0%
Mean	24.23		4.72		0.81		26.07		6.77	
Standard Deviation	0.01		0.00		0.00		0.01		0.00	
95% PI	(24.21, 24.25)		(4.72, 4.72)		(0.81, 0.81)		(26.04, 26.09)		(6.77, 6.78)	

Table 9.13 Summary statistics for stochastic sensitivity analysis, southern region

	Scenario 1 ($t_{Xsv} = -1\%$)		Scenario 2 ($t_{Ys10} = -1\%$)		Scenario 5 ($n_{Ss1} = 1\%$)		Scenario 7 ($n_{Zs1} = 1\%$)		Scenario 8 ($n_{Zs2} = 1\%$)	
	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%
Farm Production										
Base	9.00	48.6	1.80	38.3	1.06	33.5	8.89	47.1	3.2	51.1
Mean	9.02	48.7	1.76	37.5	1.04	33.0	8.91	47.2	3.2	51.0
Standard Deviation	0.83	4.488	0.21	4.37	0.15	4.77	0.93	4.95	0.37	5.94
95% PI	(7.60, 10.88)	(41.01, 58.79)	(1.38, 2.2)	(29.26, 46.79)	(0.76, 1.36)	(24.07, 43.17)	(7.14, 10.88)	(37.9, 57.7)	(2.52, 3.97)	(40.2, 63.3)
Wheat Storage										
Base	0.89	4.8	0.57	12.1	0.14	4.4	1.94	10.3	-0.07	-1.1
Mean	0.8794	4.748	0.62	13.3	0.14	4.4	1.97	10.5	-0.07	-1.2
Standard Deviation	0.2056	1.110	0.15	3.2	0.03	1.04	0.41	2.17	0.04	0.57
95% PI	(0.557, 1.345)	(3.01, 7.26)	(0.40, 0.98)	(8.51, 20.75)	(0.09, 0.21)	(2.74, 6.80)	(1.38, 2.96)	(7.29, 15.70)	(-0.15, -0.02)	(-2.43, -0.27)
Barley Storage										
Base	0.47	2.5	-0.02	-0.3	0.08	2.5	-0.09	-0.5	1.07	17.1
Mean	0.45901	2.4784%	-0.02	-0.3	0.08	2.5	-0.09	-0.5	1.08	17.3
Standard Deviation	0.10085	0.5444%	0.01	0.21	0.02	0.61	0.05	0.28	0.22	3.51
95% PI	(0.295, 0.682)	(1.59, 3.68)	(-0.04, 0.00)	(-0.83, 0.02)	(0.05, 0.13)	(1.53, 3.97)	(-0.21, -0.01)	(-1.12, -0.03)	(0.75, 1.58)	(11.93, 25.27)
Canola Storage										
Base	0.16	0.9%	-0.01	-0.1	0.01	0.2	-0.03	-0.2	-0.01	-0.2

Mean	0.16	0.86	-0.01	-0.1	0.01	0.2	-0.04	-0.2	-0.01	-0.2
Standard Deviation	0.04	0.21	0.00	0.08	0.00	0.07	0.02	0.10	0.01	0.12
95% PI	(0.1, 0.25)	(0.54, 1.36)	(-0.02, 0.00)	(-0.34, -0.02)	(0.00, 0.01)	(0.03, 0.32)	(-0.08, -0.01)	(-0.42, -0.03)	(-0.03, -0.001)	(-0.49, -0.02)
Pea Storage										
Base	0.09	0.5	0.00	0.0	0.02	0.8	-0.01	-0.1	-0.01	-0.1
Mean	0.08	0.5	0.00	-0.05	0.02	0.7	-0.02	-0.1	-0.01	-0.1
Standard Deviation	0.02	0.09	0.00	0.04	0.00	0.14	0.01	0.05	0.004	0.06
95% PI	(0.05, 0.12)	(0.29, 0.67)	(-0.01, 0.00)	(-0.14, 0.03)	(0.01, 0.03)	(0.51, 1.08)	(-0.04, 0.002)	(-0.19, 0.01)	(-0.02, -0.00)	(-0.24, -0.001)
Flour Milling										
Base	0.07	0.4	0.03	0.6	0.06	2.0	-0.04	-0.2	0.00	-0.1
Mean	0.07	0.4	0.03	0.6	0.06	2.0	-0.04	-0.2	-0.005	-0.1
Standard Deviation	0.02	0.12	0.01	0.18	0.01	0.46	0.02	0.11	0.003	0.05
95% PI	(0.03, 0.11)	(0.15, 0.6)	(0.01, 0.05)	(0.24, 0.97)	(0.04, 0.09)	(1.15, 2.96)	(-0.09, -0.004)	(-0.45, -0.02)	(-0.01, 0.00)	(-0.19, 0.003)
Stockfeed manufacturing										
Base	0.71	3.8	0.19	4.0	1.12	35.5	0.47	2.5	-0.01	-0.1
Mean	0.67	3.6	0.18	3.81	1.15	36.3	0.44	2.3	-0.009	-0.1
Standard Deviation	0.1724	0.93	0.05	1.10	0.28	8.73	0.16	0.83	0.05	0.85
95% PI	(0.404, 1.078)	(2.18, 5.82)	(0.10, 0.30)	(2.14, 6.44)	(0.75, 1.76)	(23.7, 55.6)	(0.20, 0.81)	(1.06, 4.28)	(-0.10, 0.10)	(-1.66, 1.67)

Malt Manufacturing										
Base	0.18	1.0	-0.01	-0.2	0.01	0.4	-0.04	-0.2	0.03	0.6
Mean	0.18	0.95	-0.01	-0.15	0.01	0.4	-0.04	-0.2	0.03	0.6
Standard Deviation	0.04	0.20	0.00	0.09	0.01	0.24	0.02	0.11	0.06	1.0
95% PI	(0.11, 0.26)	(0.6, 1.38)	(-0.02, -0.00)	(-0.35, --0.01)	(0.00, 0.03)	(0.07, 0.99)	(-0.08, -0.005)	(-0.45, -0.03)	(-0.07, 0.18)	(-1.12, 2.81)
Canola Processing										
Base	0.06	0.3	0.00	0.0%	0.04	1.4	-0.01	0.0	0.00	-0.1
Mean	0.06	0.3	0.00	0.00	0.04	1.4	-0.01	-0.04	0.00	-0.1
Standard Deviation	0.02	0.11	0.00	0.04	0.01	0.39	0.01	0.04	0.003	0.05
95% PI	(0.04, 0.11)	(0.19, 0.62)	(0.00, 0.00)	(-0.08, 0.08)	(0.02, 0.07)	(0.82, 2.27)	(-0.02, 0.01)	(-0.13, 0.04)	(-0.01, 0.00)	(-0.20, 0.00)
Northern Region Producer Surplus										
Base	0.15	0.8%	0.52	11.0	0.25	8.0	2.55	13.5	0.41	6.5
Mean	0.1766	0.953%	0.50	10.7	0.25	7.8	2.55	13.5	0.40	6.4
Standard Deviation	0.1975	1.066%	0.07	1.4	0.03	1.07	0.27	1.44	0.06	0.94
95% PI	(-0.14, 0.62)	(-0.76, 3.33)	(0.38, 0.65)	(8.15, 13.76)	(0.18, 0.32)	(5.77, 10.03)	(2.07, 3.13)	(10.99, 16.59)	(0.30, 0.53)	(4.83, 8.51)
Overseas Consumers										
Base	4.27	23.0	0.98	20.8	1.03	32.5	4.45	23.6	1.72	27.5
Mean	4.31	23.3	0.99	21.0	1.04	33.0	4.48	23.7	1.72	27.5
Standard Deviation	0.55	2.95	0.18	3.79	0.19	6.15	0.87	4.59	0.34	5.45

95% PI	(3.31, 5.44)	(17.88, 29.35)	(0.69, 1.4)	(14.71, 29.75)	(0.72, 1.48)	(22.9, 46.7)	(3.02, 6.47)	(17.28, 31.58)	(1.15, 2.47)	(18.4, 39.4)
Domestic Consumers										
Base	2.47	13.4	0.65	13.9	-0.67	-21.2	0.79	4.2	-0.06	-1.0
Mean	2.45	13.3	0.65	13.8	-0.68	-21.7	0.75	4.0	-0.06	-0.99
Standard Deviation	0.26	1.38	0.07	1.47	0.29	9.13	0.30	1.60	0.14	2.26
95% PI	(1.93, 2.96)	(10.44, 15.97)	(0.52, 0.79)	(11.43, 16.21)	(-1.26, -0.12)	(-39.7, -3.7)	(0.17, 1.35)	(0.88, 7.16)	(-0.32, 0.26)	(-5.14, 4.18)
Total Economic Surplus										
Base	18.52	100.0%	4.7	100.0%	3.16	100.0%	18.87	100.0%	6.26	100.0%
Mean	18.52		4.7		3.16		18.86		6.26	
Standard Deviation	0.00		0.00		0.004		0.005		0.002	
95% PI	(18.51, 18.53)		(4.7, 4.7)		(3.156, 3.16)		(18.86, 18.87)		(6.26, 6.268)	

Table 9.14 Summary statistics for stochastic sensitivity analysis, northern region

	Scenario 1 ($t_{X_{NV}} = -1\%$)		Scenario 2 ($t_{Y_{N10}} = -1\%$)		Scenario 5 ($n_{S_{N1}} = 1\%$)		Scenario 7 ($n_{Z_{N1}} = 1\%$)		Scenario 8 ($n_{Z_{N2}} = 1\%$)	
	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%
Farm Production										
Base	7.88	39.7	1.02	32.1	1.52	36.5	5.93	60.4	0.47	60.4
Mean	7.94	40.0	1.0	31.5	1.50	36.1	5.98	61.0	0.48	61.0
Standard Deviation	0.88	4.44	0.15	4.72	0.23	5.4	0.72	7.40	0.06	8.11
95% PI	(6.45, 9.91)	(32.47, 49.89)	(0.72, 1.33)	(22.62, 41.82)	(1.10, 2.01)	(26.5, 48.2)	(4.75, 7.56)	(48.4, 77.2)	(0.37, 0.62)	(47.0, 79.5)
Wheat Storage										
Base	0.51	2.5	0.25	8.0	0.13	3.2	0.78	8.0	0.00	-0.6
Mean	0.50	2.53	0.29	9.17	0.13	3.2	0.80	8.1	-0.005	-0.6
Standard Deviation	0.12	0.63	0.09	2.93	0.03	0.78	0.18	1.81	0.003	0.37
95% PI	(0.32, 0.80)	(1.59, 4.00)	(0.16, 0.50)	(4.88, 15.78)	(0.08, 0.21)	(1.99, 4.94)	(0.53, 1.22)	(5.43, 12.47)	(-0.01, -0.001)	(-1.50, -0.08)
Barley Storage										
Base	0.09	0.5	0.00	0.0	0.06	1.6	0.00	0.0	0.1	12.3
Mean	0.09	0.46	0.001	0.03	0.07	1.6	-0.004	-0.04	0.1	12.5
Standard Deviation	0.02	0.12	0.002	0.05	0.02	0.38	0.007	0.07	0.02	2.86
95% PI	(0.06, 0.15)	(0.29, 0.73)	(-0.002, 0.004)	(-0.07, 0.14)	(0.04, 0.10)	(1.02, 2.47)	(-0.02, 0.01)	(-0.21, 0.08)	(0.06, 0.15)	(8.27, 19.30)
Canola Storage										
Base	0.10	0.5	0.00	-0.1	0.01	0.2	-0.01	-0.1	0.00	-0.1

Mean	0.10	0.5	-0.002	-0.1	0.01	0.2	-0.01	-0.1	-0.001	-0.1
Standard Deviation	0.02	0.12	0.001	0.04	0.003	0.07	0.01	0.07	0.00	0.08
95% PI	(0.06, 0.16)	(0.33, 0.80)	(-0.005, 0.00)	(-0.15, -0.01)	(0.005, 0.02)	(0.11, 0.37)	(-0.03, -0.001)	(-0.31, -0.01)	(-0.003, -0.00)	(-0.33, -0.002)
Chickpea Storage										
Base	0.11	0.6	0.00	-0.1	0.00	-0.1	-0.01	-0.1	0.00	-0.2
Mean	0.11	0.55	-0.003	-0.1	-0.002	-0.1	-0.02	-0.2	-0.001	-0.2
Standard Deviation	0.03	0.13	0.001	0.04	0.002	0.04	0.01	0.08	0.001	0.09
95% PI	(0.07, 0.17)	(0.35, 0.84)	(-0.006, 0.00)	(-0.18, -0.01)	(-0.007, 0.001)	(-0.16, 0.02)	(-0.04, -0.002)	(-0.36, -0.02)	(-0.003, -0.00)	(-0.37, 0.00)
Flour Milling										
Base	0.26	1.3	0.07	2.1	0.18	4.4	-0.08	-0.8	0.00	-0.3
Mean	0.24	1.22	0.06	1.9	0.17	4.2	-0.07	-0.7	-0.002	-0.2
Standard Deviation	0.08	0.38	0.02	0.59	0.04	1.03	0.04	0.39	0.002	0.2
95% PI	(0.10, 0.40)	(0.51, 2.02)	(0.03, 0.10)	(0.88, 3.17)	(0.10, 0.26)	(2.46, 6.34)	(-0.16, -0.01)	(-1.59, -0.07)	(-0.01, 0.001)	(-0.71, 0.07)
Stockfeed manufacturing										
Base	0.95	4.8	0.17	5.3	1.30	31.2	0.40	4.0	0.01	1.0
Mean	0.91	4.6	0.16	5.0	1.34	32.2	0.37	3.7	0.01	0.9
Standard Deviation	0.23	1.18	0.04	1.39	0.32	7.70	0.13	1.34	0.01	1.64
95% PI	(0.57, 1.50)	(2.86, 7.56)	(0.09, 0.26)	(2.98, 8.11)	(0.88, 2.12)	(21.2, 50.9)	(0.16, 0.66)	(1.66, 6.77)	(-0.02, 0.03)	(-2.04, 4.35)

Malt Manufacturing										
Base	0.11	0.5	0.00	0.0	0.03	0.6	-0.01	-0.1	0.01	1.1
Mean	0.10	0.51	-0.001	-0.04	0.02	0.6	-0.01	-0.1	0.01	1.1
Standard Deviation	0.02	0.11	0.001	0.04	0.01	0.15	0.01	0.07	0.01	1.67
95% PI	(0.07, 0.15)	(0.34, 0.74)	(-0.004, 0.001)	(-0.13, --0.03)	(0.01, 0.04)	(0.32, 0.90)	(-0.02, 0.001)	(-0.27, 0.01)	(-0.02, 0.04)	(-2.19, 4.67)
Canola Processing										
Base	0.09	0.5	0.00	0.0	0.05	1.1	-0.01	-0.1	0.00	-0.1
Mean	0.09	0.5	0.0001	0.00	0.05	1.1	-0.01	-0.1	-0.001	-0.1
Standard Deviation	0.03	0.15	0.002	0.05	0.01	0.32	0.01	0.07	0.001	0.08
95% PI	(0.05, 0.16)	(0.26, 0.80)	(-0.003, 0.003)	(-0.1, 0.09)	(0.03, 0.08)	(0.68, 1.85)	(-0.02, 0.01)	(-0.24, 0.05)	(-0.002, 0.00)	(-0.3, 0.02)
Overseas Consumers										
Base	3.22	16.2	0.45	14.0	1.25	29.9	2.63	26.8	0.23	28.9
Mean	3.26	16.39	0.45	14.2	1.27	30.4	2.65	27.0	0.23	29.0
Standard Deviation	0.43	2.17	0.07	2.27	0.25	5.91	0.46	4.72	0.04	5.4
95% PI	(2.48, 4.21)	(12.48, 21.19)	(0.33, 0.61)	(10.38, 19.31)	(0.9, 1.83)	(21.5, 44.0)	(1.86, 3.74)	(18.97, 38.06)	(0.15, 0.32)	(19.77, 41.00)
Northern Region Domestic Consumers										
Base	4.73	23.8	0.92	29.0	-0.48	-11.6	0.39	4.0	0.00	0.6
Mean	4.71	23.69	0.91	28.8	-0.51	-12.3	0.33	3.4	0.002	0.2
Standard Deviation	0.41	2.04	0.07	2.09	0.35	8.35	0.34	3.45	0.04	4.91

95% PI	(3.82, 5.43)	(19.23, 27.34)	(0.77, 1.04)	(24.28, 32.74)	(-1.24, 0.16)	(-29.8, 3.8)	(-0.38, 0.95)	(-3.90, 9.69)	(-0.07, 0.08)	(-9.29, 10.05)
Southern Region Consumer Surplus										
Base	1.82	9.2	0.30	9.6	0.12	2.9	-0.19	-2.0	-0.02	-3.2
Mean	1.82	9.14	0.30	9.6	0.12	2.8	-0.2	-2.0	-0.03	-3.4
Standard Deviation	0.16	0.8	0.03	0.99	0.04	0.8	0.22	2.24	0.02	2.07
95% PI	(1.49, 2.12)	(7.52, 10.68)	(0.24, 0.37)	(7.69, 11.71)	(0.05, 0.18)	(1.22, 4.34)	(-0.6, 0.28)	(-6.15, 2.81)	(-0.06, 0.004)	(-7.72, 0.56)
Total Economic Surplus										
Base	19.87	100.0%	3.17	100.0%	4.16	100.0%	9.81	100.0%	0.78	100.0%
Mean	19.87		3.17		4.16		9.81		0.78	
Standard Deviation	0.005		0.0008		0.005		0.004		0.001	
95% PI	(19.86, 19.88)		(3.168, 3.171)		(4.15, 4.17)		(9.797, 9.813)		(0.780, 0.783)	

9.3.2 Insights Obtained from Stochastic Sensitivity Analysis

The subjective 95% probability intervals of welfare changes obtained from the simulation results represent the range of likely values of an unknown parameter based on its specified probability distribution.

As discussed in Section 8.3, the distribution of total benefits is dependent of the values assigned to the market elasticities. When the input substitution and output transformation elasticities are non-zero, the distribution of total benefits will be dependent on where in the supply chain the research occurs.

The results from Tables 9.9 to 9.11 reveal overlaps among the 95% probability intervals for both the dollar returns and the percentage shares of total benefits for each industry group between the different scenarios. For instance, the 95% probability intervals for farm production in Scenario 1 overlap with those of Scenario 7 in the Western Region. This indicates that there is a likelihood that the absolute monetary returns as well as the share of benefits received by farm production may be greater under Scenario 1 than under Scenario 7, despite the more favourable base results for Scenario 7. Consequently, this indicates the possibility that the rankings of investment scenarios provided in Chapter 8 may be different depending on the values chosen for price elasticities. This has implications for the investment decision making process.

To address this ambiguity, the simulation data can be used to calculate the probability of one investment scenario being able to deliver a higher share of returns than another investment scenario for any particular industry group. In Table 9.12, these probability comparisons for the share of total returns to farm production for each region are shown.

Table 9.15 Probability comparisons of the returns to farm production for investment scenarios by region

Western	Southern	Northern
$P((rPS_X S1) > (rPS_X S2)) = 73\%$	$P((rPS_X S1) > (rPS_X S2)) = 96\%$	$P((rPS_X S1) > (rPS_X S2)) = 91\%$
$P((rPS_X S1) > (rPS_X S5)) = 98\%$	$P((rPS_X S1) > (rPS_X S5)) = 99\%$	$P((rPS_X S1) > (rPS_X S5)) = 73\%$
$P((rPS_X S1) > (rPS_X S7)) = 39\%$	$P((rPS_X S1) > (rPS_X S7)) = 57\%$	$P((rPS_X S1) > (rPS_X S7)) = 0.6\%$
$P((rPS_X S1) > (rPS_X S8)) = 82\%$	$P((rPS_X S1) > (rPS_X S8)) = 37\%$	$P((rPS_X S1) > (rPS_X S8)) = 0.8\%$
$P((rPS_X S2) > (rPS_X S5)) = 92\%$	$P((rPS_X S2) > (rPS_X S5)) = 77\%$	$P((rPS_X S2) > (rPS_X S5)) = 25\%$
$P((rPS_X S2) > (rPS_X S7)) = 21\%$	$P((rPS_X S2) > (rPS_X S7)) = 7\%$	$P((rPS_X S2) > (rPS_X S7)) = 0.1\%$
$P((rPS_X S2) > (rPS_X S8)) = 60\%$	$P((rPS_X S2) > (rPS_X S8)) = 3\%$	$P((rPS_X S2) > (rPS_X S8)) = 0.1\%$
$P((rPS_X S5) > (rPS_X S7)) = 0.01\%$	$P((rPS_X S5) > (rPS_X S7)) = 2\%$	$P((rPS_X S5) > (rPS_X S7)) = 0.6\%$
$P((rPS_X S5) > (rPS_X S8)) = 9\%$	$P((rPS_X S5) > (rPS_X S8)) = 1\%$	$P((rPS_X S5) > (rPS_X S8)) = 0.4\%$
$P((rPS_X S7) > (rPS_X S8)) = 86\%$	$P((rPS_X S7) > (rPS_X S8)) = 31\%$	$P((rPS_X S7) > (rPS_X S8)) = 50\%$

The comparative results in Table 9.12 are consistent with the conclusions obtained in the base model. However, these results also show that different conclusions can be drawn. For instance, while the base results conclude that Scenario 7 generates a greater share of benefits to farm production compared to Scenario 1 (61.1% versus 59.4%) in the western region, stochastic sensitivity analysis suggests that there is a 39% chance that Scenario 1 may result in a higher benefit share to farm production than Scenario 7.

9.4 Summary

This chapter addressed the uncertainty associated with price elasticities. This is important given that the distribution of benefits relating to each investment scenario is dependent on the values chosen for these model parameters.

As a prelude, discrete sensitivity analysis was used to demonstrate how altering a few key elasticity values can affect the distribution of economic benefits arising from different investment scenarios. Discrete sensitivity analysis was used to test the assumption that under fixed proportions (zero input substitution and output transformation), the distribution of benefits is independent of where along the supply chain the investment in RD&E takes place. The large number of uncertain elasticity values contained in the EDMs makes it impractical to analyse the sensitivity of all uncertain parameters using traditional discrete sensitivity analysis.

To account for the uncertainty in the numerous elasticity values in the EDMs, stochastic sensitivity analysis was carried out based on the approach by Zhao *et al.* (1999). Subjective probability distributions were specified for each market elasticity, enabling probability distributions and 95% probability intervals to be derived for the resulting changes in surplus.

Chapter 10 Conclusion, Limitations and Further Research

10.1 Review and Conclusions

The grains industry is one of Australia's staple industries contributing around a quarter of Australia's total agricultural exports. The industry has grown significantly since the 1970s, yet slowing growth in total factor productivity during the 1990s and 2000s signal a major challenge for the industry. Since the late 2000s, however, the rate of annual growth in total factor productivity in grain production has recovered, especially due to more favourable seasons and the advent of new higher-yielding varieties. Advances in agricultural technology and innovations from investing in RD&E will play a key role in meeting this productivity challenge and help to promote international competitiveness.

The grains industry in Australia consists of different commodity types classified broadly into three main categories: cereal grains, oilseeds, and pulses. Geographically, there are three broad cropping regions in Australia – northern, southern, and western. Production of grains importantly requires the practice of crop rotation in helping reduce soil erosion and increasing soil fertility and crop yield, often including a pasture phase so livestock activities are an important consideration too. The grains supply chain consists of multiple stages and end phases including: production, up-country storage and transport, marketing, processing and exports. Cross-product effects between different grains in crop rotations, as well as distinctive supply chains across the three different production regions add large degrees of scale and complexity to the evaluation of benefits to RD&E in the grains industry.

As public fiscal conditions tighten so too does the imperative for accountability and measuring the potential and actual economic impacts of agricultural research. Sound investment evaluation, before and after investment, is essential. As one of the GRDC's key aims is to provide the best return on investment in order to drive the profitability of Australia's grain growing business (GRDC, 2019), having an understanding of the returns associated with different RD&E investment scenarios is therefore useful during the investment allocation and priority setting process.

Equilibrium Displacement Models (EDMs) are useful tools for evaluating anticipated returns from alternative RD&E investments and indicating the likely distribution of benefits for different participants in the value chain. EDMs have been used in many different Australian industries but as yet, no comprehensive EDM exists for the Australian grains industry. In this study, an EDM system of the Australian grains industry is constructed, accounting for the major industry groups which describes

the production, distribution and use of grains and grain products. In doing so, the study addresses the various modelling difficulties associated with the Australian grains industry, brought about by its vastness in scope along with conceptual complexities.

For modelling purposes, the study regionally disaggregated the entire industry according to the three agroecological regions defined by the GRDC—western, southern and northern. A standalone EDM is constructed for each of these regions. Due to the extensiveness of cropping activities in the industry, only the major crops in each region are modelled. As such, each regional EDM comprises four crops which represent a typical rotation sequence in that particular region.

Once developed, the three EDMs are applied by examining the impacts associated with eight hypothetical investment scenarios. For each investment scenario, a 1% exogenous shift to the relevant demand or supply curves is simulated, with the resulting displacements in prices and quantities observed, which provide estimates of both the overall annual benefits and welfare implications for each industry group within each region.

It is important to note that EDMs only estimate the potential benefits arising from different RD&E investment scenarios. The investment costs required to achieve the 1% shifts in supply and demand cannot be answered under such a framework. Therefore, comparisons between the absolute returns of different investment scenarios can only be made under the assumption of equal investment cost efficiency. However, comparisons of the shares of benefits arising for any particular industry group can be directly compared between investment scenarios without the requirement of such an assumption.

Some observations can be made about comparing the results between the different investment scenarios. Overall, the size of the total economic benefits is determined by the size of the market in which the exogenous shock takes place. The size of market is indicated by its gross revenue. As such, a 1% shift in a market with high gross revenue will yield higher total returns than a 1% shift in a market with low gross revenue. The distribution of benefits depends on the size of the market where adoption of the output of investment in RD&E occurs and the magnitude of the price elasticities.

A number of differences can be observed in the results between the three cropping regions. The western region grains industry is characterised by a short supply chain, where most of grain production is exported. The large volume of grain exported ensures that when investments in RD&E

are aimed at upstream farm production or the grain export market, some of the total benefits are enjoyed by overseas consumers. Still, a high price elasticity of demand for export grains ensures that the farm production sector receives the majority of total benefits, and that these benefits outweigh the share of benefits received by overseas consumers. The southern region grains industry also exports a majority of its grain production. As such, a similar picture is observed as in the western region. The northern region grains industry is domestically oriented, compared to the western and southern regions, with a large portion of its grain production processed domestically or sold into the southern region. Because of this, research aimed at the export grain market (Scenario 7) will generate far lower economic benefits to the industry (\$9.81 million). In addition, research that reduces the costs of farm production (Scenario 1) will also benefit consumers in the southern region.

In addition, the results show that although producers across all regions receive a substantial share from on-farm research, quality-enhancing research in the export grain market can generate even greater shares of benefits to producers, because of the elastic demand faced by overseas consumers of grain exports, enabling much of the benefits to flow back to the producers.

The base model was re-simulated using a stochastic sensitivity analysis approach to account for uncertainty in the market elasticities. Although largely consistent with the conclusions obtained in the base model, the stochastic simulation data did reveal deviations in the rankings of investment scenarios obtained for the base results. For instance, while the base results conclude that Scenario 7 generates a greater share of benefits to farm production compared to Scenario 1 (61.1% versus 59.4%), data obtained from the stochastic simulation suggests that there is a 39% chance that Scenario 1 may result in a higher benefit share to farm production than Scenario 7.

In conclusion, the three EDMs presented in this study provide a useful framework for estimating the potential returns to RD&E in the Australian grains industry in both *ex ante* and *ex post* applications. By generating information on the economic and welfare implications brought about by different investment scenarios, these EDMs serve to better inform grains RD&E investment decisions, thereby contributing to improved investment decisions by governments and funding agencies alike.

10.2 Limitations and Further Research

10.2.1 Costs of Adopting and Implementing Research Outputs

The EDMs developed in this study provide a framework for assessing the potential benefits arising from different RD&E investments, helping to guide the investment decision making process. Though, the investment costs required to achieve the 1% exogenous shifts in supply and demand cannot be answered using this framework alone. Without knowledge of the costs associated with the different investment scenarios, the absolute returns can only be compared with one another under the assumption that the investment costs required to generate each 1% shifts in supply or demand for all scenarios are equal (i.e. equal investment efficiency).

A financial appraisal of each investment scenario can be conducted once information around the investment costs are known. This allows the financial viability of investment scenarios to be assessed by comparing the initial investment outlay for each scenario with the estimated annual stream of benefits obtained from the EDM over a period time, with which the break-even point can then be determined. Similarly, a full economic appraisal or cost-benefit analysis can also be conducted which requires more comprehensive information on the economic, social as well as environmental costs and benefits.

The EDMs developed in this study can also be applied in *ex post* evaluations of actual RD&E investments. Case studies of some past RD&E investment scenarios can be examined using the EDMs, where the actual investment costs are known and where there is evidence of shifts in the supply or demand curves.

10.2.2 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 curves 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.

10.2.3 Assumption of Market Competition

Most studies of agricultural research assume that markets along the production and marketing chain are perfectly competitive; this is also the case for EDMs. For a perfectly competitive EDM, two market clearing conditions are imposed. First, profit maximisation requires that marginal costs are equal to marginal prices (revenue) in each market. Second, for a perfectly competitive EDM, the long-run competitive equilibrium condition of zero economic profit is imposed, whereby the total cost of inputs for each individual market is equal to the total revenue of its outputs. Several studies have tested for non-competitive behaviour in the grain industry. Notably, Griffith (2000) examined competition across the Australian food marketing chain. He found statistically significant evidence of non-competitive buying power exerted by grain buyers in the processing and marketing sectors. This finding was supported by O'Donnell *et al.* (2007) who tested for market power in the grains and oilseeds industries, for 13 grain and oilseed products handled by seven groups of agents.

Empirical evidence in this study suggested buyers of grain act as oligopsonists, and this was particularly evident in the wheat and barley industries. Imperfectly competitive markets can have significant implications for the estimated returns from R&D. McCorriston (2002) noted that the degree of market power influences the extent to which price changes are transferred along the

marketing chain. This could mean that price changes originating at the farm gate may not be passed fully to end consumers. Alston *et al.* (1997) examined the effects of varying degrees of market power held by agribusiness firms on the size and distribution of benefits from R&D. It was found that increasing the degree of either oligopsony or oligopoly power reduced total benefits from R&D and distorted the distribution of benefits away from consumers and producers in favour of the agribusiness firms with the power that purchased, processed and sold the raw farm products.

The research reported above highlights potential pitfalls in an EDM in which the key assumption is perfectly competitive markets. Since deregulation of the single-desk wheat marketing arrangements in Australia in 2008, competitiveness in the grains industry has heightened. 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. If non-competitive market characteristics are found then their characteristics could be incorporated in a revised EDM framework.

10.2.4 The Need for Reliable Estimates of Market Parameters

As discussed and demonstrated in Chapters 8 and 9, the model results hinge greatly on the values chosen for the market parameters, that is, the supply, demand and substitution elasticities. There is a paucity of information available in pre-existing literature on many of the elasticity values used in this study.

Of the price elasticity estimates published in literature, the majority are measured at the retail level rather than at the farm gate and are not geographically differentiated. This is challenging given that the industry is disaggregated into various industry groups across several geographic areas in this study. Moreover, many of the previous estimates reviewed in this study are dated and may not reflect current Australian agricultural conditions.

It is recommended that marketing research be carried out in updating and generating more reliable estimates of these market parameters, particularly for the broad acre industry, which would enable more robust modelling results.

10.3 Final Remarks

This study provides a modelling framework in measuring the potential returns to different types of RD&E investments in the Australian grains industry. Due to its vastness in scope, the study disaggregates the entire industry according to the three agroecological regions defined by the GRDC—western, southern and northern. For each region, a standalone EDM is constructed, incorporating the major crops that represent a common cropping sequence unique to the region. Each regional industry is then disaggregated into the various major market segments comprising the supply chain. In effect, this enables comparisons to be made around the economic benefits that different RD&E investments can have on each region, as well as providing insight on how the benefits are then distribution across the various industry groups in each region. This is particularly useful for examining the impacts of investments that are regional specific. Accordingly, the study bridges a gap in existing literature by providing an EDM system for the Australian grains industry at a comprehensive scale. When applied, it can generate information to assist investment decisions by RD&E funders and other parties seeking to boost the profitability of various parts of Australia's grains industry.

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Appendix A The Equilibrium Displacement Models

Equilibrium Displacement Model of the Western Region

1. Farm Production

1.1 Input supply to farm enterprises

$$(A.1) EX_{wv} = \varepsilon_{Xwv,wwv} * (Ew_{wv} - t_{Xwv})$$

$$(A.2) EX_{wo} = \varepsilon_{Xwo,wwo} * (Ew_{wo} - t_{Xwo})$$

1.2 Output constrained input demands of farm enterprises

$$(A.3) EX_{wv} = \tilde{\eta}_{Xwv,wwv} * Ew_{wv} + \tilde{\eta}_{Xwv,wwo} * Ew_{wo} + EY^w$$

$$(A.4) EX_{wo} = \tilde{\eta}_{Xwo,wwo} * Ew_{wo} + \tilde{\eta}_{Xwo,wwv} * Ew_{wv} + EY^w$$

1.3 Input constrained output supplies of farm enterprises

$$(A.5) EY_{w1} = \tilde{\varepsilon}_{Yw1,vw1} * Ev_{w1} + \tilde{\varepsilon}_{Yw1,vw2} * Ev_{w2} + \tilde{\varepsilon}_{Yw1,vw3} * Ev_{w3} + \tilde{\varepsilon}_{Yw1,vw4} * Ev_{w4} + EX^w$$

$$(A.6) EY_{w2} = \tilde{\varepsilon}_{Yw2,vw2} * Ev_{w2} + \tilde{\varepsilon}_{Yw2,vw1} * Ev_{w1} + \tilde{\varepsilon}_{Yw2,vw3} * Ev_{w3} + \tilde{\varepsilon}_{Yw2,vw4} * Ev_{w4} + EX^w$$

$$(A.7) EY_{w3} = \tilde{\varepsilon}_{Yw3,vw3} * Ev_{w3} + \tilde{\varepsilon}_{Yw3,vw1} * Ev_{w1} + \tilde{\varepsilon}_{Yw3,vw2} * Ev_{w2} + \tilde{\varepsilon}_{Yw3,vw4} * Ev_{w4} + EX^w$$

$$(A.8) EY_{w4} = \tilde{\varepsilon}_{Yw4,vw4} * Ev_{w4} + \tilde{\varepsilon}_{Yw4,vw1} * Ev_{w1} + \tilde{\varepsilon}_{Yw4,vw2} * Ev_{w2} + \tilde{\varepsilon}_{Yw4,vw3} * Ev_{w3} + EX^w$$

1.4 Equilibrium conditions

$$(A.9) \kappa_{Xwv} * EX_{wv} + \kappa_{Xwo} * EX_{wo} = \lambda_{Yw1} * EY_{w1} + \lambda_{Yw2} * EY_{w2} + \lambda_{Yw3} * EY_{w3} + \lambda_{Yw4} * EY_{w4}$$

$$(A.10) \kappa_{Xwv} * Ew_{wv} + \kappa_{Xwo} * Ew_{wo} = \lambda_{Yw1} * Ev_{w1} + \lambda_{Yw2} * Ev_{w2} + \lambda_{Yw3} * Ev_{w3} + \lambda_{Yw4} * Ev_{w4}$$

2. Wheat Storage

2.1 Input supply to wheat storage

$$(A.11) EY_{w10} = \varepsilon_{Yw10,vw10} * (Ev_{w10} - t_{Yw10})$$

2.2 Output constrained input demands of wheat storage

$$(A.12) EY_{w1} = \tilde{\eta}_{Yw1,vw1} * Ev_{w1} + \tilde{\eta}_{Yw1,vw10} * Ev_{w10} + EZ^{ww}$$

$$(A.13) EY_{w10} = \tilde{\eta}_{Yw10,vw10} * Ev_{w10} + \tilde{\eta}_{Yw10,vw1} * Ev_{w1} + EZ^{ww}$$

2.3 Input constrained output supply of wheat storage

$$(A.14) EZ_{w1} = \tilde{\varepsilon}_{Zw1,uw1} * Eu_{w1} + \tilde{\varepsilon}_{Zw1,uw5} * Eu_{w5} + \tilde{\varepsilon}_{Zw1,uw6} * Eu_{w6} + EY^{ww}$$

$$(A.15) EZ_{w5} = \tilde{\varepsilon}_{Zw5,uw5} * Eu_{w5} + \tilde{\varepsilon}_{Zw5,uw1} * Eu_{w1} + \tilde{\varepsilon}_{Zw5,uw6} * Eu_{w6} + EY^{ww}$$

$$(A.16) EZ_{w6} = \tilde{\varepsilon}_{Zw6,uw6} * Eu_{w6} + \tilde{\varepsilon}_{Zw6,uw1} * Eu_{w1} + \tilde{\varepsilon}_{Zw6,uw5} * Eu_{w5} + EY^{ww}$$

2.4 Equilibrium conditions

$$(A.17) \kappa_{Yw1} * EY_{w1} + \kappa_{Yw1o} * EY_{w1o} = \lambda_{Zw1} * EZ_{w1} + \lambda_{Zw5} * EZ_{w5} + \lambda_{Zw6} * EZ_{w6}$$

$$(A.18) \kappa_{vw1} * EV_{w1} + \kappa_{vw1o} * EV_{w1o} = \lambda_{uw1} * Eu_{w1} + \lambda_{uw5} * Eu_{w5} + \lambda_{uw6} * Eu_{w6}$$

2.5 Export Demand

$$(A.19) EZ_{w1} = \eta_{Zw1,uw1} * (Eu_{w1} - n_{Zw1})$$

3. Barley Storage

3.1 Input supply to barley storage

$$(A.20) EY_{w2o} = \varepsilon_{Yw2o,vw2o} * (EV_{w2o} - t_{Yw2o})$$

3.2 Output constrained input demands of barley storage

$$(A.21) EY_{w2} = \tilde{\eta}_{Yw2,vw2} * EV_{w2} + \tilde{\eta}_{Yw2,vw2o} * EV_{w2o} + EZ^{wb}$$

$$(A.22) EY_{w2o} = \tilde{\eta}_{Yw2o,vw2o} * EV_{w2o} + \tilde{\eta}_{Yw2o,vw2} * EV_{w2} + EZ^{wb}$$

3.3 Input constrained output supply of barley storage

$$(A.23) EZ_{w2} = \tilde{\varepsilon}_{Zw2,uw2} * Eu_{w2} + \tilde{\varepsilon}_{Zw2,uw7} * Eu_{w7} + \tilde{\varepsilon}_{Zw2,uw8} * Eu_{w8} + EY^{wb}$$

$$(A.24) EZ_{w7} = \tilde{\varepsilon}_{Zw7,uw7} * Eu_{w7} + \tilde{\varepsilon}_{Zw7,uw2} * Eu_{w2} + \tilde{\varepsilon}_{Zw7,uw8} * Eu_{w8} + EY^{wb}$$

$$(A.25) EZ_{w8} = \tilde{\varepsilon}_{Zw8,uw8} * Eu_{w8} + \tilde{\varepsilon}_{Zw8,uw2} * Eu_{w2} + \tilde{\varepsilon}_{Zw8,uw7} * Eu_{w7} + EY^{wb}$$

3.4 Equilibrium conditions

$$(A.26) \kappa_{Yw2} * EY_{w2} + \kappa_{Yw2o} * EY_{w2o} = \lambda_{Zw2} * EZ_{w2} + \lambda_{Zw7} * EZ_{w7} + \lambda_{Zw8} * EZ_{w8}$$

$$(A.27) \kappa_{vw2} * EV_{w2} + \kappa_{vw2o} * EV_{w2o} = \lambda_{uw2} * Eu_{w2} + \lambda_{uw7} * Eu_{w7} + \lambda_{uw8} * Eu_{w8}$$

3.5 Export Demand

$$(A.28) EZ_{w2} = \eta_{Zw2,uw2} * (Eu_{w2} - n_{Zw2})$$

4. Canola Storage

4.1 Input supply to canola storage

$$(A.29) EY_{w3o} = \varepsilon_{Yw3o,vw3o} * (EV_{w3o} - t_{Yw3o})$$

4.2 Output constrained input demands of canola storage

$$(A.30) EY_{w3} = \tilde{\eta}_{Yw3,vw3} * EV_{w3} + \tilde{\eta}_{Yw3,vw3o} * EV_{w3o} + EZ^{wc}$$

$$(A.31) EY_{w3o} = \tilde{\eta}_{Yw3o,vw3o} * EV_{w3o} + \tilde{\eta}_{Yw3o,vw3} * EV_{w3} + EZ^{wc}$$

4.3 Input constrained output supply of canola storage

$$(A.32) EZ_{w3} = \tilde{\varepsilon}_{Zw3,uw3} * Eu_{w3} + \tilde{\varepsilon}_{Zw3,uw9} * Eu_{w9} + EY^{wc}$$

$$(A.33) EZ_{w9} = \tilde{\varepsilon}_{Zw9,uw9} * Eu_{w9} + \tilde{\varepsilon}_{Zw9,uw3} * Eu_{w3} + EY^{wc}$$

4.4 Equilibrium conditions

$$(A.34) \kappa_{Yw3} * EY_{w3} + \kappa_{Yw3o} * EY_{w3o} = \lambda_{Zw3} * EZ_{w3} + \lambda_{Zw9} * EZ_{w9}$$

$$(A.35) \kappa_{vw3} * EV_{w3} + \kappa_{vw3o} * EV_{w3o} = \lambda_{uw3} * Eu_{w3} + \lambda_{uw9} * Eu_{w9}$$

4.5 Export Demand

$$(A.36) EZ_{w3} = \eta_{Zw3,uw3} * (Eu_{w3} - n_{Zw3})$$

5. Lupin Storage

5.1 Input supply to lupin storage

$$(A.37) EY_{w4o} = \varepsilon_{Yw4o,vw4o} * (EV_{w4o} - t_{Yw4o})$$

5.2 Output constraints input demands of lupin storage

$$(A.38) EY_{w4} = \tilde{\eta}_{Yw4,vw4} * EV_{w4} + \tilde{\eta}_{Yw4,vw4o} * EV_{w4o} + EZ^{wl}$$

$$(A.39) EY_{w4o} = \tilde{\eta}_{Yw4o,vw4o} * EV_{w4o} + \tilde{\eta}_{Yw4o,vw4} * EV_{w4} + EZ^{wl}$$

5.3 Input constrained output supply of lupin storage

$$(A.40) EZ_{w4} = \tilde{\varepsilon}_{Zw4,uw4} * Eu_{w4} + \tilde{\varepsilon}_{Zw4,uw10} * Eu_{w10} + EY^{wl}$$

$$(A.41) EZ_{w10} = \tilde{\varepsilon}_{Zw10,uw10} * Eu_{w10} + \tilde{\varepsilon}_{Zw10,uw4} * Eu_{w4} + EY^{wl}$$

5.4 Equilibrium conditions

$$(A.42) \kappa_{Yw4} * EY_{w4} + \kappa_{Yw4o} * EY_{w4o} = \lambda_{Zw4} * EZ_{w4} + \lambda_{Zw10} * EZ_{w10}$$

$$(A.43) \kappa_{vw4} * EV_{w4} + \kappa_{vw4o} * EV_{w4o} = \lambda_{uw4} * Eu_{w4} + \lambda_{uw10} * Eu_{w10}$$

5.5 Export Demand

$$(A.44) EZ_{w4} = \eta_{Zw4,uw4} * (Eu_{w4} - n_{Zw4})$$

6. Flour Milling

6.1 Input supply to flour milling

$$(A.45) EF_{w0} = \varepsilon_{Fw0,gw0} * (Eg_{w0} - t_{Fw0})$$

6.2 Output constrained input demand of flour milling

$$(A.46) EZ_{w5} = \tilde{\eta}_{Zw5,uw5} * Eu_{w5} + \tilde{\eta}_{Zw5,gw0} * Eg_{w0} + EF^w$$

$$(A.47) EF_{w0} = \tilde{\eta}_{Fw0,gw0} * Eg_{w0} + \tilde{\eta}_{Fw0,uw5} * Eu_{w5} + EF^w$$

6.3 Input constrained output supply of flour milling

$$(A.48) EF_{w1} = \tilde{\varepsilon}_{Fw1,gw1} * Eg_{w1} + \tilde{\varepsilon}_{Fw1,gw2} * Eg_{w2} + EZ^{wf}$$

$$(A.49) EF_{w2} = \tilde{\epsilon}_{Fw2,gw2} * Eg_{w2} + \tilde{\epsilon}_{Fw2,gw1} * Eg_{w1} + EZ^{wf}$$

6.4 Equilibrium conditions

$$(A.50) \kappa_{Zw5} * EZ_{w5} + \kappa_{Fw0} * EF_{w0} = \lambda_{Fw1} * EF_{w1} + \lambda_{Fw2} * EF_{w2}$$

$$(A.51) \kappa_{uw5} * Eu_{w5} + \kappa_{gwo} * Eg_{wo} = \lambda_{gw1} * Eg_{w1} + \lambda_{gw2} * Eg_{w2}$$

6.5 Domestic demand

$$(A.52) EF_{w1} = \eta_{Fw1,gw1} * (g_{w1} - n_{Fw1})$$

7. Stockfeed Manufacturing

7.1 Input supply to stockfeed manufacturing

$$(A.53) ES_{wo} = \epsilon_{Swo,two} * (Et_{wo} - t_{Swo})$$

7.2 Output constrained input demand of stockfeed manufacturing

$$(A.54) EZ_{w6} = \tilde{\eta}_{Zw6,uw6} * Eu_{w6} + \tilde{\eta}_{Zw6,uw7} * Eu_{w7} + \tilde{\eta}_{Zw6,uw10} * Eu_{w10} + \tilde{\eta}_{Zw6,dw1} * Ed_{w1} + \tilde{\eta}_{Zw6,gw2} * Eg_{w2} + \tilde{\eta}_{Zw6,two} * Et_{wo} + ES^w$$

$$(A.55) EZ_{w7} = \tilde{\eta}_{Zw7,uw7} * Eu_{w7} + \tilde{\eta}_{Zw7,uw6} * Eu_{w6} + \tilde{\eta}_{Zw7,uw10} * Eu_{w10} + \tilde{\eta}_{Zw7,dw1} * Ed_{w1} + \tilde{\eta}_{Zw7,gw2} * Eg_{w2} + \tilde{\eta}_{Zw7,two} * Et_{wo} + ES^w$$

$$(A.56) EZ_{w10} = \tilde{\eta}_{Zw10,uw10} * Eu_{w10} + \tilde{\eta}_{Zw10,uw6} * Eu_{w6} + \tilde{\eta}_{Zw10,uw7} * Eu_{w7} + \tilde{\eta}_{Zw10,dw1} * Ed_{w1} + \tilde{\eta}_{Zw10,gw2} * Eg_{w2} + \tilde{\eta}_{Zw10,two} * Et_{wo} + ES^w$$

$$(A.57) EF_{w2} = \tilde{\eta}_{Fw2,gw2} * Eg_{w2} + \tilde{\eta}_{Fw2,uw6} * Eu_{w6} + \tilde{\eta}_{Fw2,uw7} * Eu_{w7} + \tilde{\eta}_{Fw2,uw10} * Eu_{w10} + \tilde{\eta}_{Fw2,dw1} * Ed_{w1} + \tilde{\eta}_{Fw2,two} * Et_{wo} + ES^w$$

$$(A.58) EC_{w1} = \tilde{\eta}_{Cw1,dw1} * Ed_{w1} + \tilde{\eta}_{Cw1,uw6} * Eu_{w6} + \tilde{\eta}_{Cw1,uw7} * Eu_{w7} + \tilde{\eta}_{Cw1,uw10} * Eu_{w10} + \tilde{\eta}_{Cw1,gw2} * Eg_{w2} + \tilde{\eta}_{Cw1,two} * Et_{wo} + ES^w$$

$$(A.59) ES_{wo} = \tilde{\eta}_{Swo,two} * Et_{wo} + \tilde{\eta}_{Swo,uw6} * Eu_{w6} + \tilde{\eta}_{Swo,uw7} * Eu_{w7} + \tilde{\eta}_{Swo,uw10} * Eu_{w10} + \tilde{\eta}_{Swo,dw1} * Ed_{w1} + \tilde{\eta}_{Swo,fw2} * Eg_{w2} + ES^w$$

7.3 Input constrained output supply of stockfeed manufacturing

$$(A.60) ES_{w1} = \tilde{\epsilon}_{Sw1,tw1} * Et_{w1} + \tilde{\epsilon}_{Sw1,tw2} * Et_{w2} + EZ^{ws}$$

$$(A.61) ES_{w2} = \tilde{\epsilon}_{Sw2,tw2} * Et_{w2} + \tilde{\epsilon}_{Sw2,tw1} * Et_{w1} + EZ^{ws}$$

7.4 Equilibrium conditions

$$(A.62) \kappa_{Zw6} * EZ_{w6} + \kappa_{Zw7} * EZ_{w7} + \kappa_{Zw10} * EZ_{w10} + \kappa_{Cw1} * EC_{w1} + \kappa_{Fw2} * EF_{w2} + \kappa_{Swo} * ES_{wo} = \lambda_{Sw1} * ES_{w1} + \lambda_{Sw2} * ES_{w2}$$

$$(A.63) \kappa_{uw6} * Eu_{w6} + \kappa_{uw7} * Eu_{w7} + \kappa_{uw10} * Eu_{w10} + \kappa_{dw1} * Ed_{w1} + \kappa_{gw2} * Eg_{w2} + \kappa_{two} * Et_{wo} = \lambda_{tw1} * Et_{w1} + \lambda_{tw2} * Et_{w2}$$

7.5 Export demand

$$(A.64) ES_{w1} = \eta_{Sw1,tw1} * (t_{w1} - n_{Sw1})$$

7.6 Domestic demand

$$(A.65) ES_{w2} = \eta_{Sw2,tw2} * (t_{w2} - n_{Sw2})$$

8. Malt Manufacturing

8.1 Input supply to stockfeed manufacturing

$$(A.66) EM_{w0} = \varepsilon_{Mw0,nw0} * (En_{w0} - t_{Mw0})$$

8.2 Output constrained input demand of malt manufacturing

$$(A.67) EZ_{w8} = \tilde{\eta}_{Zw8,uw8} * Eu_{w8} + \tilde{\eta}_{Zw8,nw0} * En_{w0} + EM^w$$

$$(A.68) EM_{w0} = \tilde{\eta}_{Mw0,nw0} * En_{w0} + \tilde{\eta}_{Mw0,uw8} * Eu_{w8} + EM^w$$

8.3 Input constrained output supply of malt manufacturing

$$(A.69) EM_{w1} = \tilde{\varepsilon}_{Mw1,nw1} * En_{w1} + \tilde{\varepsilon}_{Mw1,nw2} * En_{w2} + EZ^{wm}$$

$$(A.70) EM_{w2} = \tilde{\varepsilon}_{Mw2,nw2} * En_{w2} + \tilde{\varepsilon}_{Mw2,nw1} * En_{w1} + EZ^{wm}$$

8.4 Equilibrium conditions

$$(A.71) \kappa_{Zw8} * EZ_{w8} + \kappa_{Mw0} * EM_{w0} = \lambda_{Mw1} * EM_{w1} + \lambda_{Mw2} * EM_{w2}$$

$$(A.72) \kappa_{uw8} * Eu_{w8} + \kappa_{nw0} * En_{w0} = \lambda_{nw1} * En_{w1} + \lambda_{nw2} * En_{w2}$$

8.5 Export demand

$$(A.73) EM_{w1} = \eta_{Mw1,tw1} * (t_{w1} - n_{Mw1})$$

8.6 Domestic demand

$$(A.74) EM_{w2} = \eta_{Mw2,tw2} * (t_{w2} - n_{Mw2})$$

9. Oilseed Crushing and Refining

9.1 Input supply to oilseed crushing and refining

$$(A.75) EC_{w0} = \varepsilon_{Cw0,dw0} * (Ed_{w0} - t_{Cw0})$$

9.2 Output constrained input demand of oilseed crushing and refining

$$(A.76) EZ_{w9} = \tilde{\eta}_{Zw9,uw9} * Eu_{w9} + \tilde{\eta}_{Zw9,dw0} * Ed_{w0} + EC^w$$

$$(A.77) EC_{w0} = \tilde{\eta}_{Cw0,dw0} * Ed_{w0} + \tilde{\eta}_{Cw0,uw9} * Eu_{w9} + EC^w$$

9.3 Input constrained output supply of oilseed crushing and refining

$$(A.78) EC_{w1} = \tilde{\varepsilon}_{Cw1,dw1} * Ed_{w1} + \tilde{\varepsilon}_{Cw1,dw2} * Ed_{w2} + \tilde{\varepsilon}_{Cw1,dw3} * Ed_{w3} + EZ^{wc}$$

$$(A.79) EC_{w2} = \tilde{\varepsilon}_{Cw2,dw2} * Ed_{w2} + \tilde{\varepsilon}_{Cw2,dw1} * Ed_{w1} + \tilde{\varepsilon}_{Cw2,dw3} * Ed_{w3} + EZ^{wc}$$

$$(A.80) EC_{w3} = \tilde{\varepsilon}_{Cw3,dw3} * Ed_{w3} + \tilde{\varepsilon}_{Cw3,dw1} * Ed_{w1} + \tilde{\varepsilon}_{Cw3,dw2} * Ed_{w2} + EZ^{wc}$$

9.4 Equilibrium conditions

$$(A.81) \kappa_{Zw9} * EZ_{w9} + \kappa_{Cw0} * EC_{w0} = \lambda_{Cw1} * EC_{w1} + \lambda_{Cw2} * EC_{w2}$$

$$(A.82) \kappa_{uw9} * Eu_{w9} + \kappa_{dw0} * Ed_{w0} = \lambda_{dw1} * Ed_{w1} + \lambda_{dw2} * Ed_{w2}$$

9.5 Export demand

$$(A.83) \text{ EC}_{w2} = \eta_{cw2,dw2} * (d_{w2} - n_{cw2})$$

9.6 Domestic demand

$$(A.84) \text{ EC}_{w3} = \eta_{cw2,dw2} * (d_{w2} - n_{dw2})$$

Equilibrium Displacement Model of the Southern Region

1. Farm

1.1 Input supply to farm enterprises

$$(A.85) EX_{sv} = \varepsilon_{Xsv,wsv} * (Ew_{sv} - t_{Xsv})$$

$$(A.86) EX_{so} = \varepsilon_{Xso,wsso} * (Ew_{so} - t_{Xso})$$

1.2 Output constrained input demands of farm enterprises

$$(A.87) EX_{sv} = \tilde{\eta}_{Xsv,wsv} * Ew_{sv} + \tilde{\eta}_{Xsv,wsso} * Ew_{so} + EY^s$$

$$(A.88) EX_{so} = \tilde{\eta}_{Xso,wsso} * Ew_{so} + \tilde{\eta}_{Xso,wsv} * Ew_{sv} + EY^s$$

1.3 Input constrained output supplies of farm enterprises

$$(A.89) EY_{s1} = \tilde{\varepsilon}_{Ys1,vs1} * Ev_{s1} + \tilde{\varepsilon}_{Ys1,vs2} * Ev_{s2} + \tilde{\varepsilon}_{Ys1,vs3} * Ev_{s3} + \tilde{\varepsilon}_{Ys1,vs4} * Ev_{s4} + EX^s$$

$$(A.90) EY_{s2} = \tilde{\varepsilon}_{Ys2,vs2} * Ev_{s2} + \tilde{\varepsilon}_{Ys2,vs1} * Ev_{s1} + \tilde{\varepsilon}_{Ys2,vs3} * Ev_{s3} + \tilde{\varepsilon}_{Ys2,vs4} * Ev_{s4} + EX^s$$

$$(A.91) EY_{s3} = \tilde{\varepsilon}_{Ys3,vs3} * Ev_{s3} + \tilde{\varepsilon}_{Ys3,vs1} * Ev_{s1} + \tilde{\varepsilon}_{Ys3,vs2} * Ev_{s2} + \tilde{\varepsilon}_{Ys3,vs4} * Ev_{s4} + EX^s$$

$$(A.92) EY_{s4} = \tilde{\varepsilon}_{Ys4,vs4} * Ev_{s4} + \tilde{\varepsilon}_{Ys4,vs1} * Ev_{s1} + \tilde{\varepsilon}_{Ys4,vs2} * Ev_{s2} + \tilde{\varepsilon}_{Ys4,vs3} * Ev_{s3} + EX^s$$

1.4 Equilibrium conditions

$$(A.93) \kappa_{Xsv} * EX_{sv} + \kappa_{Xso} * EX_{so} = \lambda_{Ys1} * EY_{s1} + \lambda_{Ys2} * EY_{s2} + \lambda_{Ys3} * EY_{s3} + \lambda_{Ys4} * EY_{s4}$$

$$(A.94) \kappa_{Xsv} * Ew_{sv} + \kappa_{Xso} * Ew_{so} = \lambda_{Ys1} * Ev_{s1} + \lambda_{Ys2} * Ev_{s2} + \lambda_{Ys3} * Ev_{s3} + \lambda_{Ys4} * Ev_{s4}$$

2. Wheat Storage

2.1 Input supply to wheat storage

$$(A.95) EY_{s10} = \varepsilon_{Ys10,vs10} * (Ev_{s10} - t_{Ys10})$$

2.2 Inter-regional wheat supply to wheat storage

$$(A.96) EY_{s5} = \varepsilon_{Ys5,vs5} * (Ev_{s5} - t_{Ys5})$$

2.3 Output constrained input demands of wheat storage

$$(A.97) EY_{s1} = \tilde{\eta}_{Ys1,vs1} * Ev_{s1} + \tilde{\eta}_{Ys1,vs10} * Ev_{s10} + \tilde{\eta}_{Ys1,vs5} * Ev_{s5} + EZ^{sw}$$

$$(A.98) EY_{s5} = \tilde{\eta}_{Ys5,vs5} * Ev_{s5} + \tilde{\eta}_{Ys5,vs1} * Ev_{s1} + \tilde{\eta}_{Ys5,vs10} * Ev_{s10} + EZ^{sw}$$

$$(A.99) EY_{s10} = \tilde{\eta}_{Ys10,vs10} * Ev_{s10} + \tilde{\eta}_{Ys10,vs1} * Ev_{s1} + \tilde{\eta}_{Ys10,vs5} * Ev_{s5} + EZ^{sw}$$

2.4 Input constrained output supply of wheat storage

$$(A.100) EZ_{s1} = \tilde{\varepsilon}_{Zs1,us1} * Eu_{s1} + \tilde{\varepsilon}_{Zs1,us5} * Eu_{s5} + \tilde{\varepsilon}_{Zs1,us6} * Eu_{s6} + EY^{sw}$$

$$(A.101) EZ_{s5} = \tilde{\varepsilon}_{Zs5,us5} * Eu_{s5} + \tilde{\varepsilon}_{Zs5,us1} * Eu_{s1} + \tilde{\varepsilon}_{Zs5,us6} * Eu_{s6} + EY^{sw}$$

$$(A.102) EZ_{s6} = \tilde{\varepsilon}_{Zs6,us6} * Eu_{s6} + \tilde{\varepsilon}_{Zs5,us1} * Eu_{s1} + \tilde{\varepsilon}_{Zs6,us5} * Eu_{s5} + EY^{sw}$$

2.5 Equilibrium conditions

$$(A.103) \kappa_{Ys1} * EY_{s1} + \kappa_{Ys5} * EY_{s5} + \kappa_{Ys10} * EY_{s10} = \lambda_{Zs1} * EZ_{s1} + \lambda_{Zs5} * EZ_{s5} + \lambda_{Zs6} * EZ_{s6}$$

$$(A.104) \kappa_{Vs1} * EV_{s1} + \kappa_{Vs5} * EV_{s5} + \kappa_{Vs10} * EV_{s10} = \lambda_{us1} * Eu_{s1} + \lambda_{us5} * Eu_{s5} + \lambda_{us6} * Eu_{s6}$$

2.6 Export demand

$$(A.105) EZ_{s1} = \eta_{Zs1,us1} * (Eu_{s1} - n_{Zs1})$$

3. Barley Storage

3.1 Input supply to barley storage

$$(A.106) EY_{s20} = \varepsilon_{Ys20,vs20} * (EV_{s20} - t_{Ys20})$$

3.2 Inter-regional barley supply to barley storage

$$(A.107) EY_{s6} = \varepsilon_{Ys6,vs6} * (EV_{s6} - t_{Ys6})$$

3.3 Output constrained input demands of barley storage

$$(A.108) EY_{s2} = \tilde{\eta}_{Ys2,vs2} * EV_{s2} + \tilde{\eta}_{Ys2,vs20} * EV_{s20} + \tilde{\eta}_{Ys2,vs6} * EV_{s6} + EZ^{sb}$$

$$(A.109) EY_{s6} = \tilde{\eta}_{Ys6,vs6} * EV_{s6} + \tilde{\eta}_{Ys6,vs2} * EV_{s2} + \tilde{\eta}_{Ys6,vs20} * EV_{s20} + EZ^{sb}$$

$$(A.110) EY_{s20} = \tilde{\eta}_{Ys20,vs20} * EV_{s20} + \tilde{\eta}_{Ys20,vs2} * EV_{s2} + \tilde{\eta}_{Ys20,vs6} * EV_{s6} + EZ^{sb}$$

3.4 Input constrained output supply of barley storage

$$(A.111) EZ_{s2} = \tilde{\varepsilon}_{Zs2,us2} * Eu_{s2} + \tilde{\varepsilon}_{Zs2,us7} * Eu_{s7} + \tilde{\varepsilon}_{Zs2,us8} * Eu_{s8} + EY^{sb}$$

$$(A.112) EZ_{s7} = \tilde{\varepsilon}_{Zs7,us7} * Eu_{s7} + \tilde{\varepsilon}_{Zs7,us2} * Eu_{s2} + \tilde{\varepsilon}_{Zs7,us8} * Eu_{s8} + EY^{sb}$$

$$(A.113) EZ_{s8} = \tilde{\varepsilon}_{Zs8,us8} * Eu_{s8} + \tilde{\varepsilon}_{Zs8,us2} * Eu_{s2} + \tilde{\varepsilon}_{Zs8,us7} * Eu_{s7} + EY^{sb}$$

3.5 Equilibrium conditions

$$(A.114) \kappa_{Ys2} * EY_{s2} + \kappa_{Ys6} * EY_{s6} + \kappa_{Ys20} * EY_{s20} = \lambda_{Zs2} * EZ_{s2} + \lambda_{Zs7} * EZ_{s7} + \lambda_{Zs8} * EZ_{s8}$$

$$(A.115) \kappa_{Vs2} * EV_{s2} + \kappa_{Vs6} * EV_{s6} + \kappa_{Vs20} * EV_{s20} = \lambda_{us2} * Eu_{s2} + \lambda_{us7} * Eu_{s7} + \lambda_{us8} * Eu_{s8}$$

3.6 Export demand

$$(A.116) EZ_{s2} = \eta_{Zs2,us2} * (Eu_{s2} - n_{Zs2})$$

4. Canola Storage

4.1 Input supply to canola storage

$$(A.117) EY_{s30} = \varepsilon_{Ys30,vs30} * (EV_{s30} - t_{Ys30})$$

4.2 Inter-regional canola supply to canola storage

$$(A.118) EY_{s7} = \varepsilon_{Ys7,vs7} * (EV_{s7} - t_{Ys7})$$

4.3 Output constrained input demands of canola storage

$$(A.119) EY_{s3} = \tilde{\eta}_{Ys3,vs3} * EV_{s3} + \tilde{\eta}_{Ys3,vs30} * EV_{s30} + \tilde{\eta}_{Ys3,vs7} * EV_{s7} + EZ^{sc}$$

$$(A.120) EY_{s7} = \tilde{\eta}_{Ys7,vs7} * EV_{s7} + \tilde{\eta}_{Ys7,vs3} * EV_{s3} + \tilde{\eta}_{Ys7,vs30} * EV_{s30} + EZ^{sc}$$

$$(A.121) EY_{s30} = \tilde{\eta}_{Ys30,vs30} * EV_{s30} + \tilde{\eta}_{Ys30,vs3} * EV_{s3} + \tilde{\eta}_{Ys30,vs7} * EV_{s7} + EZ^{sc}$$

4.4 Input constrained output supply of canola storage

$$(A.122) EZ_{s3} = \tilde{\varepsilon}_{Zs3,us3} * Eu_{s3} + \tilde{\varepsilon}_{Zs3,us9} * Eu_{s9} + EY^{sc}$$

$$(A.123) EZ_{s9} = \tilde{\varepsilon}_{Zs9,us9} * Eu_{s9} + \tilde{\varepsilon}_{Zs9,us3} * Eu_{s3} + EY^{sc}$$

4.5 Equilibrium conditions

$$(A.124) \kappa_{Ys3} * EY_{s3} + \kappa_{Ys7} * EY_{s7} + \kappa_{Ys30} * EY_{s30} = \lambda_{Zs3} * EZ_{s3} + \lambda_{Zs9} * EZ_{s9}$$

$$(A.125) \kappa_{vs3} * EV_{s3} + \kappa_{vs7} * EV_{s7} + \kappa_{vs30} * EV_{s30} = \lambda_{us3} * Eu_{s3} + \lambda_{us9} * Eu_{s9}$$

4.6 Export demand

$$(A.126) EZ_{s3} = \eta_{Zs3,us3} * (Eu_{s3} - n_{Zs3})$$

5. Lupin Storage**5.1 Input supply to lupin storage**

$$(A.127) EY_{s40} = \varepsilon_{Ys40,vs40} * (EV_{s40} - t_{Ys40})$$

5.2 Output constraints input demands of lupin storage

$$(A.128) EY_{s4} = \tilde{\eta}_{Ys4,vs4} * EV_{s4} + \tilde{\eta}_{Ys4,vs40} * EV_{s40} + EZ^{sl}$$

$$(A.129) EY_{s40} = \tilde{\eta}_{Ys40,vs40} * EV_{s40} + \tilde{\eta}_{Ys40,vs4} * EV_{s4} + EZ^{sl}$$

5.3 Input constrained output supply of lupin storage

$$(A.130) EZ_{s4} = \tilde{\varepsilon}_{Zs4,us4} * Eu_{s4} + \tilde{\varepsilon}_{Zs4,us10} * Eu_{s10} + EY^{sl}$$

$$(A.131) EZ_{s10} = \tilde{\varepsilon}_{Zs10,us10} * Eu_{s10} + \tilde{\varepsilon}_{Zs10,us4} * Eu_{s4} + EY^{sl}$$

5.4 Equilibrium conditions

$$(A.132) \kappa_{Ys4} * EY_{s4} + \kappa_{Ys40} * EY_{s40} = \lambda_{Zs4} * EZ_{s4} + \lambda_{Zs10} * EZ_{s10}$$

$$(A.133) \kappa_{vs4} * EV_{s4} + \kappa_{vs40} * EV_{s40} = \lambda_{us4} * Eu_{s4} + \lambda_{us10} * Eu_{s10}$$

5.5 Export Demand

$$(A.134) EZ_{s4} = \eta_{Zs4,us4} * (Eu_{s4} - n_{Zs4})$$

6. Flour Milling

6.1 Input supply to flour milling

$$(A.135) EF_{so} = \varepsilon_{Fso,gs0} * (Eg_{so} - t_{Fso})$$

6.2 Output constrained input demand of flour milling

$$(A.136) EZ_{s5} = \tilde{\eta}_{Zs5,us5} * Eu_{s5} + \tilde{\eta}_{Zs5,gs0} * Eg_{so} + EF^s$$

$$(A.137) EF_{so} = \tilde{\eta}_{Fso,gs0} * Eg_{so} + \tilde{\eta}_{Fso,us5} * Eu_{s5} + EF^s$$

6.3 Input constrained output supply of flour milling

$$(A.138) EF_{s1} = \tilde{\varepsilon}_{Fs1,gs1} * Eg_{s1} + \tilde{\varepsilon}_{Fs1,gs2} * Eg_{s2} + EZ^{sf}$$

$$(A.139) EF_{s2} = \tilde{\varepsilon}_{Fs2,gs2} * Eg_{s2} + \tilde{\varepsilon}_{Fs2,gs1} * Eg_{s1} + EZ^{sf}$$

6.4 Equilibrium conditions

$$(A.140) \kappa_{Zs5} * EZ_{s5} + \kappa_{Fso} * EF_{so} = \lambda_{Fs1} * EF_{s1} + \lambda_{Fs2} * EF_{s2}$$

$$(A.141) \kappa_{us5} * Eu_{s5} + \kappa_{gs0} * Eg_{so} = \lambda_{gs1} * Eg_{s1} + \lambda_{gs2} * Eg_{s2}$$

6.5 Domestic demand

$$(A.142) EF_{s1} = \eta_{Fs1,gs1} * (g_{s1} - n_{Fs1})$$

7. Stockfeed Manufacturing

7.1 Input supply to stockfeed manufacturing

$$(A.143) ES_{so} = \varepsilon_{Sso,tso} * (Et_{so} - t_{Sso})$$

7.2 Output constrained input demand of stockfeed manufacturing

$$(A.144) EZ_{s6} = \tilde{\eta}_{Zs6,us6} * Eu_{s6} + \tilde{\eta}_{Zs6,us7} * Eu_{s7} + \tilde{\eta}_{Zs6,us10} * Eu_{s10} + \tilde{\eta}_{Zs6,ds1} * Ed_{s1} + \tilde{\eta}_{Zs6,gs2} * Eg_{s2} + \tilde{\eta}_{Zs6,tso} * Et_{so} + ES^s$$

$$(A.145) EZ_{s7} = \tilde{\eta}_{Zs7,us7} * Eu_{s7} + \tilde{\eta}_{Zs7,us6} * Eu_{s6} + \tilde{\eta}_{Zs7,us10} * Eu_{s10} + \tilde{\eta}_{Zs7,ds1} * Ed_{s1} + \tilde{\eta}_{Zs7,gs2} * Eg_{s2} + \tilde{\eta}_{Zs7,tso} * Et_{so} + ES^s$$

$$(A.146) EZ_{s10} = \tilde{\eta}_{Zs10,us10} * Eu_{s10} + \tilde{\eta}_{Zs10,us6} * Eu_{s6} + \tilde{\eta}_{Zs10,us7} * Eu_{s7} + \tilde{\eta}_{Zs10,ds1} * Ed_{s1} + \tilde{\eta}_{Zs10,gs2} * Eg_{s2} + \tilde{\eta}_{Zs10,tso} * Et_{so} + ES^s$$

$$(A.147) EF_{s2} = \tilde{\eta}_{Fs2,gs2} * Eg_{s2} + \tilde{\eta}_{Fs2,us6} * Eu_{s6} + \tilde{\eta}_{Fs2,us7} * Eu_{s7} + \tilde{\eta}_{Fs2,us10} * Eu_{s10} + \tilde{\eta}_{Fs2,ds1} * Ed_{s1} + \tilde{\eta}_{Fs2,tso} * Et_{so} + ES^s$$

$$(A.148) EC_{s1} = \tilde{\eta}_{Cs1,ds1} * Ed_{s1} + \tilde{\eta}_{Cs1,us6} * Eu_{s6} + \tilde{\eta}_{Cs1,us7} * Eu_{s7} + \tilde{\eta}_{Cs1,us10} * Eu_{s10} + \tilde{\eta}_{Cs1,gs2} * Eg_{s2} + \tilde{\eta}_{Cs1,tso} * Et_{so} + ES^s$$

$$(A.149) ES_{so} = \tilde{\eta}_{Sso,tso} * Et_{so} + \tilde{\eta}_{Sso,us6} * Eu_{s6} + \tilde{\eta}_{Sso,us7} * Eu_{s7} + \tilde{\eta}_{Sso,us10} * Eu_{s10} + \tilde{\eta}_{Sso,ds1} * Ed_{s1} + \tilde{\eta}_{Sso,gs2} * Eg_{s2} + ES^s$$

7.3 Input constrained output supply of stockfeed manufacturing

$$(A.150) ES_{s1} = \tilde{\varepsilon}_{Ss1,ts1} * Et_{s1} + \tilde{\varepsilon}_{Ss1,ts2} * Et_{s2} + EZ^{ss}$$

$$(A.151) ES_{s2} = \tilde{\varepsilon}_{Ss2,ts2} * Et_{s2} + \tilde{\varepsilon}_{Ss2,ts1} * Et_{s1} + EZ^{ss}$$

7.4 Equilibrium conditions

$$(A.152) \kappa_{Zs6} * EZ_{s6} + \kappa_{Zs7} * EZ_{s7} + \kappa_{Zs10} * EZ_{s10} + \kappa_{Cs1} * EC_{s1} + \kappa_{Fs2} * EF_{s2} + \kappa_{Sso} * ES_{so} = \lambda_{Ss1} * ES_{s1} + \lambda_{Ss2} * ES_{s2}$$

$$(A.153) \kappa_{us6} * Eu_{s6} + \kappa_{us7} * Eu_{s7} + \kappa_{us10} * Eu_{s10} + \kappa_{ds1} * Ed_{s1} + \kappa_{gs2} * Eg_{s2} + \kappa_{tso} * Et_{so} = \lambda_{ts1} * Et_{s1} + \lambda_{ts2} * Et_{s2}$$

7.5 Export demand

$$(A.154) ES_{s1} = \eta_{Ss1,ts1} * (t_{s1} - n_{Ss1})$$

7.6 Domestic demand

$$(A.155) ES_{s2} = \eta_{Ss2,ts2} * (t_{s2} - n_{Ss2})$$

8. Malt Manufacturing**8.1 Input supply to stockfeed manufacturing**

$$(A.156) EM_{so} = \epsilon_{Mso,nso} * (En_{so} - t_{Mso})$$

8.2 Output constrained input demand of malt manufacturing

$$(A.157) EZ_{s8} = \tilde{\eta}_{Zs8,us8} * Eu_{s8} + \tilde{\eta}_{Zs8,nso} * En_{so} + EM^s$$

$$(A.158) EM_{so} = \tilde{\eta}_{Mso,nso} * En_{so} + \tilde{\eta}_{Mso,us8} * Eu_{s8} + EM^s$$

8.3 Input constrained output supply of malt manufacturing

$$(A.159) EM_{s1} = \tilde{\epsilon}_{Ms1,ns1} * En_{s1} + \tilde{\epsilon}_{Ms1,ns2} * En_{s2} + EZ^{sm}$$

$$(A.160) EM_{s2} = \tilde{\epsilon}_{Ms2,ns2} * En_{s2} + \tilde{\epsilon}_{Ms2,ns1} * En_{s1} + EZ^{sm}$$

8.4 Equilibrium conditions

$$(A.161) \kappa_{Zs8} * EZ_{s8} + \kappa_{Mso} * EM_{so} = \lambda_{Ms1} * EM_{s1} + \lambda_{Ms2} * EM_{s2}$$

$$(A.162) \kappa_{us8} * Eu_{s8} + \kappa_{nso} * En_{so} = \lambda_{ns1} * En_{s1} + \lambda_{ns2} * En_{s2}$$

8.5 Export demand

$$(A.163) EM_{s1} = \eta_{Ms1,ts1} * (t_{s1} - n_{Ms1})$$

8.6 Domestic demand

$$(A.164) EM_{s2} = \eta_{Ms2,ts2} * (t_{s2} - n_{Ms2})$$

9. Oilseed Crushing and Refining**9.1 Input supply to oilseed crushing and refining**

$$(A.165) EC_{so} = \epsilon_{Cso,dso} * (Ed_{so} - t_{Cso})$$

9.2 Output constrained input demand of oilseed crushing and refining

$$(A.166) EZ_{s9} = \tilde{\eta}_{Zs9,us9} * Eu_{s9} + \tilde{\eta}_{Zs9,dso} * Ed_{so} + EC^s$$

$$(A.167) EC_{so} = \tilde{\eta}_{Cso,dso} * Ed_{so} + \tilde{\eta}_{Cso,us9} * Eu_{s9} + EC^s$$

9.3 Input constrained output supply of oilseed crushing and refining

$$(A.168) EC_{s1} = \tilde{\epsilon}_{Cs1,ds1} * Ed_{s1} + \tilde{\epsilon}_{Cs1,ds2} * Ed_{s2} + \tilde{\epsilon}_{Cs1,ds3} * Ed_{s3} + EZ^{sc}$$

$$(A.169) EC_{s2} = \tilde{\epsilon}_{Cs2,ds2} * Ed_{s2} + \tilde{\epsilon}_{Cs2,ds1} * Ed_{s1} + \tilde{\epsilon}_{Cs2,ds3} * Ed_{s3} + EZ^{sc}$$

$$(A.170) EC_{s3} = \tilde{\epsilon}_{Cs3,ds3} * Ed_{s3} + \tilde{\epsilon}_{Cs3,ds1} * Ed_{s1} + \tilde{\epsilon}_{Cs3,ds2} * Ed_{s2} + EZ^{sc}$$

9.4 Equilibrium conditions

$$(A.171) \kappa_{Zs9} * EZ_{s9} + \kappa_{Cso} * EC_{so} = \lambda_{Cs1} * EC_{s1} + \lambda_{Cs2} * EC_{s2}$$

$$(A.172) \kappa_{us9} * Eu_{s9} + \kappa_{dso} * Ed_{so} = \lambda_{ds1} * Ed_{s1} + \lambda_{ds2} * Ed_{s2}$$

9.5 Export demand

$$(A.173) EC_{s2} = \eta_{Cs2,ds2} * (d_{s2} - n_{Cs2})$$

9.6 Domestic demand

$$(A.174) EC_{s3} = \eta_{Cs2,ds2} * (d_{s2} - n_{ds2})$$

Equilibrium Displacement Model of the Northern Region

1. Farm

1.1 Input supply to farm enterprises

$$(A.175) EX_{nv} = \varepsilon_{Xnv,wnv} * (EW_{nv} - t_{Xnv})$$

$$(A.176) EX_{no} = \varepsilon_{Xno,wno} * (EW_{no} - t_{Xno})$$

1.2 Output constrained input demands of farm enterprises

$$(A.177) EX_{nv} = \tilde{\eta}_{Xnv,wnv} * EW_{nv} + \tilde{\eta}_{Xnv,wno} * EW_{no} + EY^n$$

$$(A.178) EX_{no} = \tilde{\eta}_{Xno,wno} * EW_{no} + \tilde{\eta}_{Xno,wnv} * EW_{nv} + EY^n$$

1.3 Input constrained output supplies of farm enterprises

$$(A.179) EY_{n1} = \tilde{\varepsilon}_{Yn1,vn1} * EV_{n1} + \tilde{\varepsilon}_{Yn1,vn2} * EV_{n2} + \tilde{\varepsilon}_{Yn1,vn3} * EV_{n3} + \tilde{\varepsilon}_{Yn1,vn4} * EV_{n4} + EX^n$$

$$(A.180) EY_{n2} = \tilde{\varepsilon}_{Yn2,vn2} * EV_{n2} + \tilde{\varepsilon}_{Yn2,vn1} * EV_{n1} + \tilde{\varepsilon}_{Yn2,vn3} * EV_{n3} + \tilde{\varepsilon}_{Yn2,vn4} * EV_{n4} + EX^n$$

$$(A.181) EY_{n3} = \tilde{\varepsilon}_{Yn3,vn3} * EV_{n3} + \tilde{\varepsilon}_{Yn3,vn1} * EV_{n1} + \tilde{\varepsilon}_{Yn3,vn2} * EV_{n2} + \tilde{\varepsilon}_{Yn3,vn4} * EV_{n4} + EX^n$$

$$(A.182) EY_{n4} = \tilde{\varepsilon}_{Yn4,vn4} * EV_{n4} + \tilde{\varepsilon}_{Yn4,vn1} * EV_{n1} + \tilde{\varepsilon}_{Yn4,vn2} * EV_{n2} + \tilde{\varepsilon}_{Yn4,vn3} * EV_{n3} + EX^n$$

1.4 Equilibrium conditions

$$(A.183) \kappa_{Xnv} * EX_{nv} + \kappa_{Xno} * EX_{no} = \lambda_{Yn1} * EY_{n1} + \lambda_{Yn2} * EY_{n2} + \lambda_{Yn3} * EY_{n3} + \lambda_{Yn4} * EY_{n4}$$

$$(A.184) \kappa_{Xnv} * En_{nv} + \kappa_{Xno} * En_{no} = \lambda_{Yn1} * EV_{n1} + \lambda_{Yn2} * EV_{n2} + \lambda_{Yn3} * EV_{n3} + \lambda_{Yn4} * EV_{n4}$$

2. Wheat Storage

2.1 Input supply to wheat storage

$$(A.185) EY_{s10} = \varepsilon_{Yn10,vn10} * (EV_{n10} - t_{Yn10})$$

2.2 Output constrained input demands of wheat storage

$$(A.186) EY_{n1} = \tilde{\eta}_{Yn1,vn1} * EV_{n1} + \tilde{\eta}_{Yn1,vn10} * EV_{n10} + EZ^{nw}$$

$$(A.187) EY_{n10} = \tilde{\eta}_{Yn10,vn10} * EV_{n10} + \tilde{\eta}_{Yn10,vn1} * EV_{n1} + EZ^{nw}$$

2.3 Input constrained output supply of wheat storage

$$(A.188) EZ_{n1} = \tilde{\varepsilon}_{Zn1,un1} * EU_{n1} + \tilde{\varepsilon}_{Zn1,un5} * EU_{n5} + \tilde{\varepsilon}_{Zn1,un6} * EU_{n6} + \tilde{\varepsilon}_{Zn1,un11} * EU_{n11} + EY^{nw}$$

$$(A.189) EZ_{n5} = \tilde{\varepsilon}_{Zn5,un5} * EU_{n5} + \tilde{\varepsilon}_{Zn5,un1} * EU_{n1} + \tilde{\varepsilon}_{Zn5,un6} * EU_{n6} + \tilde{\varepsilon}_{Zn5,un11} * EU_{n11} + EY^{nw}$$

$$(A.190) EZ_{n6} = \tilde{\varepsilon}_{Zn6,un6} * EU_{n6} + \tilde{\varepsilon}_{Zn6,un1} * EU_{n1} + \tilde{\varepsilon}_{Zn6,un5} * EU_{n5} + \tilde{\varepsilon}_{Zn6,un11} * EU_{n11} + EY^{nw}$$

$$(A.191) EZ_{n11} = \tilde{\varepsilon}_{Zn11,un11} * EU_{n11} + \lambda_{Zn1} * \tau_{Zn11,Zn1} * EU_{n1} + \lambda_{Zn5} * \tau_{Zn11,Zn5} * EU_{n5} + \lambda_{Zn6} * \tau_{Zn11,Zn6} * EU_{n6} + EY^{nw}$$

2.4 Equilibrium conditions

$$(A.192) \kappa_{Yn1} * EY_{n1} + \kappa_{Yn10} * EY_{n10} = \lambda_{zn1} * EZ_{n1} + \lambda_{zn5} * EZ_{n5} + \lambda_{zn6} * EZ_{n6} + \lambda_{zn11} * EZ_{n11}$$

$$(A.193) \kappa_{vn1} * EV_{n1} + \kappa_{vn10} * EV_{n10} = \lambda_{un1} * Eu_{n1} + \lambda_{un5} * Eu_{n5} + \lambda_{un6} * Eu_{n6} + \lambda_{un11} * Eu_{n11}$$

2.5 Export demand

$$(A.194) EZ_{n1} = \eta_{zn1,un1} * (Eu_{n1} - n_{zn1})$$

2.5 Domestic demand from other region

$$(A.195) EZ_{11} = \eta_{zn11,un11} * (Eu_{n11} - n_{zn11})$$

3. Barley Storage**3.1 Input supply to barley storage**

$$(A.196) EY_{n20} = \varepsilon_{Yn20,vn20} * (EV_{n20} - t_{Yn20})$$

3.2 Output constrained input demands of barley storage

$$(A.197) EY_{n2} = \tilde{\eta}_{Yn2,vn2} * EV_{n2} + \tilde{\eta}_{Yn2,vn20} * EV_{n20} + EZ^{nb}$$

$$(A.198) EY_{n20} = \tilde{\eta}_{Yn20,vn20} * EV_{n20} + \tilde{\eta}_{Yn20,vn2} * EV_{n2} + EZ^{nb}$$

3.3 Input constrained output supply of barley storage

$$(A.199) EZ_{n2} = \tilde{\varepsilon}_{zn2,un2} * Eu_{n2} + \tilde{\varepsilon}_{zn2,un7} * Eu_{n7} + \tilde{\varepsilon}_{zn2,un8} * Eu_{n8} + \tilde{\varepsilon}_{zn2,un12} * Eu_{n12} + EY^{nb}$$

$$(A.200) EZ_{n7} = \tilde{\varepsilon}_{zn7,un7} * Eu_{n7} + \tilde{\varepsilon}_{zn7,un2} * Eu_{n2} + \tilde{\varepsilon}_{zn7,un8} * Eu_{n8} + \tilde{\varepsilon}_{zn7,un12} * Eu_{n12} + EY^{nb}$$

$$(A.201) EZ_{n8} = \tilde{\varepsilon}_{zn8,un8} * Eu_{n8} + \tilde{\varepsilon}_{zn8,un2} * Eu_{n2} + \tilde{\varepsilon}_{zn8,un7} * Eu_{n7} + \tilde{\varepsilon}_{zn8,un12} * Eu_{n12} + EY^{nb}$$

$$(A.202) EZ_{n12} = \tilde{\varepsilon}_{zn12,un12} * Eu_{n12} + \tilde{\varepsilon}_{zn12,un2} * Eu_{n2} + \tilde{\varepsilon}_{zn12,un7} * Eu_{n7} + \tilde{\varepsilon}_{zn12,un8} * Eu_{n8} + EY^{nb}$$

3.4 Equilibrium conditions

$$(A.203) \kappa_{Yn2} * EY_{n2} + \kappa_{Yn20} * EY_{n20} = \lambda_{zn2} * EZ_{n2} + \lambda_{zn7} * EZ_{n7} + \lambda_{zn8} * EZ_{n8} + \lambda_{zn12} * EZ_{n12}$$

$$(A.204) \kappa_{vn2} * EV_{n2} + \kappa_{vn20} * EV_{n20} = \lambda_{un2} * Eu_{n2} + \lambda_{un7} * Eu_{n7} + \lambda_{un8} * Eu_{n8} + \lambda_{un12} * Eu_{n12}$$

3.5 Export demand

$$(A.205) EZ_{n2} = \eta_{zn2,un2} * (Eu_{n2} - n_{zn2})$$

3.5 Demand from other region

$$(A.206) EZ_{n12} = \eta_{zn12,un12} * (Eu_{n2} - n_{zn12})$$

4. Canola Storage**4.1 Input supply to canola storage**

$$(A.207) EY_{n30} = \varepsilon_{Yn30,vn30} * (EV_{n30} - t_{Yn30})$$

4.2 Output constrained input demands of canola storage

$$(A.208) EY_{n3} = \tilde{\eta}_{Yn3,vn3} * EV_{n3} + \tilde{\eta}_{Yn3,vn3o} * EV_{n3o} + EZ^{nc}$$

$$(A.209) EY_{n3o} = \tilde{\eta}_{Yn3o,vn3o} * EV_{n3o} + \tilde{\eta}_{Yn3o,vn3} * EV_{n3} + EZ^{nc}$$

4.3 Input constrained output supply of canola storage

$$(A.210) EZ_{n3} = \tilde{\varepsilon}_{Zn3,un3} * Eu_{n3} + \tilde{\varepsilon}_{Zn3,un9} * Eu_{n9} + \tilde{\varepsilon}_{Zn3,un13} * Eu_{n13} + EY^{nc}$$

$$(A.211) EZ_{n9} = \tilde{\varepsilon}_{Zn9,un9} * Eu_{n9} + \tilde{\varepsilon}_{Zn9,un3} * Eu_{n3} + \tilde{\varepsilon}_{Zn9,un13} * Eu_{n13} + EY^{nc}$$

$$(A.212) EZ_{n13} = \tilde{\varepsilon}_{Zn13,un13} * Eu_{n13} + \tilde{\varepsilon}_{Zn13,un3} * Eu_{n3} + \tilde{\varepsilon}_{Zn13,un9} * Eu_{n9} + EY^{nc}$$

4.4 Equilibrium conditions

$$(A.213) \kappa_{Yn3} * EY_{n3} + \kappa_{Yn3o} * EY_{n3o} = \lambda_{Zn3} * EZ_{n3} + \lambda_{Zn9} * EZ_{n9} + \lambda_{Zn13} * EZ_{n13}$$

$$(A.214) \kappa_{vn3} * EV_{n3} + \kappa_{vn3o} * EV_{n3o} = \lambda_{un3} * Eu_{n3} + \lambda_{un9} * Eu_{n9} + \lambda_{un13} * Eu_{n13}$$

4.5 Export demand

$$(A.215) EZ_{n3} = \eta_{Zn3,un3} * (Eu_{n3} - n_{Zn3})$$

4.5 Demand from other region

$$(A.216) EZ_{n3} = \eta_{Zn3,un3} * (Eu_{n3} - n_{Zn3})$$

5. Lupin Storage**5.1 Input supply to lupin storage**

$$(A.217) EY_{n4o} = \varepsilon_{Yn4o,vn4o} * (EV_{n4o} - t_{Yn4o})$$

5.2 Output constraints input demands of lupin storage

$$(A.218) EY_{n4} = \tilde{\eta}_{Yn4,vn4} * EV_{n4} + \tilde{\eta}_{Yn4,vn4o} * EV_{n4o} + EZ^{nl}$$

$$(A.219) EY_{n4o} = \tilde{\eta}_{Yn4o,vn4o} * EV_{n4o} + \tilde{\eta}_{Yn4o,vn4} * EV_{n4} + EZ^{nl}$$

5.3 Input constrained output supply of lupin storage

$$(A.220) EZ_{n4} = \tilde{\varepsilon}_{Zn4,un4} * Eu_{n4} + \tilde{\varepsilon}_{Zn4,un10} * Eu_{n10} + EY^{nl}$$

$$(A.221) EZ_{n10} = \tilde{\varepsilon}_{Zn10,un10} * Eu_{n10} + \tilde{\varepsilon}_{Zn10,un4} * Eu_{n4} + EY^{nl}$$

5.4 Equilibrium conditions

$$(A.222) \kappa_{Yn4} * EY_{n4} + \kappa_{Yn4o} * EY_{n4o} = \lambda_{Zn4} * EZ_{n4} + \lambda_{Zn10} * EZ_{n10}$$

$$(A.223) \kappa_{vn4} * EV_{n4} + \kappa_{vn4o} * EV_{n4o} = \lambda_{un4} * Eu_{n4} + \lambda_{un10} * Eu_{n10}$$

5.5 Export Demand

$$(A.224) EZ_{n4} = \eta_{Zn4,un4} * (Eu_{n4} - n_{Zn4})$$

6. Flour Milling

6.1 Input supply to flour milling

$$(A.225) EF_{no} = \varepsilon_{Fno, gno} * (Eg_{no} - t_{Fno})$$

6.2 Output constrained input demand of flour milling

$$(A.226) EZ_{n5} = \tilde{\eta}_{Zn5, un5} * Eu_{n5} + \tilde{\eta}_{Zn5, gno} * Eg_{no} + EF^n$$

$$(A.227) EF_{no} = \tilde{\eta}_{Fno, gno} * Eg_{no} + \tilde{\eta}_{Fno, un5} * Eu_{n5} + EF^n$$

6.3 Input constrained output supply of flour milling

$$(A.228) EF_{n1} = \tilde{\varepsilon}_{Fn1, gn1} * Eg_{n1} + \tilde{\varepsilon}_{Fn1, gn2} * Eg_{n2} + EZ^{nf}$$

$$(A.229) EF_{n2} = \tilde{\varepsilon}_{Fn2, gn2} * Eg_{n2} + \tilde{\varepsilon}_{Fn2, gn1} * Eg_{n1} + EZ^{nf}$$

6.4 Equilibrium conditions

$$(A.230) \kappa_{Zn5} * EZ_{n5} + \kappa_{Fno} * EF_{no} = \lambda_{Fn1} * EF_{n1} + \lambda_{Fn2} * EF_{n2}$$

$$(A.231) \kappa_{un5} * Eu_{n5} + \kappa_{gno} * Eg_{no} = \lambda_{gn1} * Eg_{n1} + \lambda_{gn2} * Eg_{n2}$$

6.5 Domestic demand

$$(A.232) EF_{n1} = \eta_{Fn1, gn1} * (g_{n1} - n_{Fn1})$$

7. Stockfeed Manufacturing

7.1 Input supply to stockfeed manufacturing

$$(A.233) ES_{no} = \varepsilon_{Sno, tno} * (Et_{no} - t_{Sno})$$

7.2 Output constrained input demand of stockfeed manufacturing

$$(A.234) EZ_{n6} = \tilde{\eta}_{Zn6, un6} * Eu_{n6} + \tilde{\eta}_{Zn6, un7} * Eu_{n7} + \tilde{\eta}_{Zn6, un10} * Eu_{n10} + \tilde{\eta}_{Zn6, dn1} * Ed_{n1} + \tilde{\eta}_{Zn6, gn2} * Eg_{n2} + \tilde{\eta}_{Zn6, tno} * Et_{no} + ES^n$$

$$(A.235) EZ_{n7} = \tilde{\eta}_{Zn7, un7} * Eu_{n7} + \tilde{\eta}_{Zn7, un6} * Eu_{n6} + \tilde{\eta}_{Zn7, un10} * Eu_{n10} + \tilde{\eta}_{Zn7, dn1} * Ed_{n1} + \tilde{\eta}_{Zn7, gn2} * Eg_{n2} + \tilde{\eta}_{Zn7, tno} * Et_{no} + ES^n$$

$$(A.236) EZ_{n10} = \tilde{\eta}_{Zn10, un10} * Eu_{n10} + \tilde{\eta}_{Zn10, un6} * Eu_{n6} + \tilde{\eta}_{Zn10, un7} * Eu_{n7} + \tilde{\eta}_{Zn10, dn1} * Ed_{n1} + \tilde{\eta}_{Zn10, gn2} * Eg_{n2} + \tilde{\eta}_{Zn10, tno} * Et_{no} + ES^n$$

$$(A.237) EF_{n2} = \tilde{\eta}_{Fn2, gn2} * Eg_{n2} + \tilde{\eta}_{Fn2, un6} * Eu_{n6} + \tilde{\eta}_{Fn2, un7} * Eu_{n7} + \tilde{\eta}_{Fn2, un10} * Eu_{n10} + \tilde{\eta}_{Fn2, dn1} * Ed_{n1} + \tilde{\eta}_{Fn2, tno} * Et_{no} + ES^n$$

$$(A.238) EC_{n1} = \tilde{\eta}_{Cn1, dn1} * Ed_{n1} + \tilde{\eta}_{Cn1, un6} * Eu_{n6} + \tilde{\eta}_{Cn1, un7} * Eu_{n7} + \tilde{\eta}_{Cn1, un10} * Eu_{n10} + \tilde{\eta}_{Cn1, gn2} * Eg_{n2} + \tilde{\eta}_{Cn1, tno} * Et_{no} + ES^n$$

$$(A.239) ES_{no} = \tilde{\eta}_{Sno, tno} * Et_{no} + \tilde{\eta}_{Sno, un6} * Eu_{n6} + \tilde{\eta}_{Sno, un7} * Eu_{n7} + \tilde{\eta}_{Sno, un10} * Eu_{n10} + \tilde{\eta}_{Sno, dn1} * Ed_{n1} + \tilde{\eta}_{Sno, gn2} * Eg_{n2} + ES^n$$

7.3 Input constrained output supply of stockfeed manufacturing

$$(A.240) ES_{n1} = \tilde{\varepsilon}_{Sn1, tn1} * Et_{n1} + \tilde{\varepsilon}_{Sn1, tn2} * Et_{n2} + EZ^{ns}$$

$$(A.241) ES_{n2} = \tilde{\varepsilon}_{Sn2, tn2} * Et_{n2} + \tilde{\varepsilon}_{Sn2, tn1} * Et_{n1} + EZ^{ns}$$

7.4 Equilibrium conditions

$$(A.242) \kappa_{Zn6} * EZ_{n6} + \kappa_{Zn7} * EZ_{n7} + \kappa_{Zn10} * EZ_{n10} + \kappa_{Cn1} * EC_{n1} + \kappa_{Fn2} * EF_{n2} + \kappa_{Sno} * ES_{no} = \lambda_{Sn1} * ES_{n1} + \lambda_{Sn2} * ES_{n2}$$

$$(A.243) \kappa_{un6} * Eu_{n6} + \kappa_{un7} * Eu_{n7} + \kappa_{un10} * Eu_{n10} + \kappa_{dn1} * Ed_{n1} + \kappa_{gn2} * Eg_{n2} + \kappa_{tno} * Et_{no} = \lambda_{tn1} * Et_{n1} + \lambda_{tn2} * Et_{n2}$$

7.5 Export demand

$$(A.244) ES_{n1} = \eta_{Sn1,tn1} * (t_{n1} - n_{Sn1})$$

7.6 Domestic demand

$$(A.245) ES_{n2} = \eta_{Sn2,tn2} * (t_{n2} - n_{Sn2})$$

8. Malt Manufacturing**8.1 Input supply to stockfeed manufacturing**

$$(A.246) EM_{no} = \varepsilon_{Mno, nno} * (En_{no} - t_{Mno})$$

8.2 Output constrained input demand of malt manufacturing

$$(A.247) EZ_{n8} = \tilde{\eta}_{Zn8,un8} * Eu_{n8} + \tilde{\eta}_{Zn8,uno} * En_{no} + EM^n$$

$$(A.248) EM_{no} = \tilde{\eta}_{Zno,uno} * En_{no} + \tilde{\eta}_{Zno,un8} * Eu_{n8} + EM^n$$

8.3 Input constrained output supply of malt manufacturing

$$(A.249) EM_{n1} = \tilde{\varepsilon}_{Mn1,nn1} * En_{n1} + \tilde{\varepsilon}_{Mn1,nn2} * En_{n2} + EZ^{nm}$$

$$(A.250) EM_{n2} = \tilde{\varepsilon}_{Mn2,nn2} * En_{n2} + \tilde{\varepsilon}_{Mn2,nn1} * En_{n1} + EZ^{nm}$$

8.4 Equilibrium conditions

$$(A.251) \kappa_{Zn8} * EZ_{n8} + \kappa_{Mno} * EM_{no} = \lambda_{Mn1} * EM_{n1} + \lambda_{Mn2} * EM_{n2}$$

$$(A.252) \kappa_{un8} * Eu_{n8} + \kappa_{nno} * En_{no} = \lambda_{nn1} * En_{n1} + \lambda_{nn2} * En_{n2}$$

8.5 Export demand

$$(A.253) EM_{n1} = \eta_{Mn1,tn1} * (t_{n1} - n_{Mn1})$$

8.6 Domestic demand

$$(A.254) EM_{n2} = \eta_{Mn2,tn2} * (t_{n2} - n_{Mn2})$$

9. Oilseed Crushing and Refining**9.1 Input supply to oilseed crushing and refining**

$$(A.255) EC_{no} = \varepsilon_{Cno,dno} * (Ed_{no} - t_{Cno})$$

9.2 Output constrained input demand of oilseed crushing and refining

$$(A.256) EZ_{n9} = \tilde{\eta}_{Zn9,un9} * Eu_{n9} + \tilde{\eta}_{Zn9,dno} * Ed_{no} + EC^n$$

$$(A.257) EC_{no} = \tilde{\eta}_{Cno,dno} * Ed_{no} + \tilde{\eta}_{Cno,un9} * Eu_{n9} + EC^n$$

9.3 Input constrained output supply of oilseed crushing and refining

$$(A.258) \quad EC_{n1} = \tilde{\eta}_{Cn1,dn1} * Ed_{n1} + \tilde{\eta}_{Cn1,dn2} * Ed_{n2} + \tilde{\eta}_{Cn1,dn3} * Ed_{n3} + EZ^{nc}$$

$$(A.259) \quad EC_{n2} = \tilde{\eta}_{Cn2,dn2} * Ed_{n2} + \tilde{\eta}_{Cn2,dn1} * Ed_{n1} + \tilde{\eta}_{Cn2,dn3} * Ed_{n3} + EZ^{nc}$$

$$(A.260) \quad EC_{n3} = \tilde{\eta}_{Cn3,dn3} * Ed_{n3} + \tilde{\eta}_{Cn3,dn1} * Ed_{n1} + \tilde{\eta}_{Cn3,dn2} * Ed_{n2} + EZ^{nc}$$

9.4 Equilibrium conditions

$$(A.261) \quad \kappa_{zn9} * EZ_{w9} + \kappa_{cno} * EC_{no} = \lambda_{cw1} * EC_{n1} + \lambda_{cw2} * EC_{n2}$$

$$(A.262) \quad \kappa_{un9} * Eu_{w9} + \kappa_{dno} * Ed_{no} = \lambda_{dw1} * Ed_{n1} + \lambda_{dw2} * Ed_{n2}$$

9.5 Export demand

$$(A.263) \quad EC_{n2} = \eta_{cn2,dn2} * (d_{n2} - n_{cn2})$$

9.6 Domestic demand

$$(A.264) \quad EC_{n3} = \eta_{cn2,dn2} * (d_{n2} - n_{dn2})$$

Appendix B The Equilibrium Displacement Models with Integrability Conditions Imposed

Equilibrium Displacement Model of the Western Region

1. Farm Production

1.1 Input supply to farm enterprises

$$(B.1) EX_{wv} = \varepsilon_{Xwv,wwv} * (EW_{wv} - t_{Xwv})$$

$$(B.2) EX_{wo} = \varepsilon_{Xwo,wwv} * (EW_{wo} - t_{Xwo})$$

1.2 Output constrained input demands of farm enterprises

$$(B.3) EX_{wv} = -\kappa_{Xwo} * \sigma_{Xwv,Xwo} * EW_{wv} + \kappa_{Xwo} * \sigma_{Xwv,Xwo} * EW_{wo} + EY^w$$

$$(B.4) EX_{wo} = -\kappa_{Xwv} * \sigma_{Xwv,Xwo} * EW_{wo} + \kappa_{Xwv} * \sigma_{Xwv,Xwo} * EW_{wv} + EY^w$$

1.3 Input constrained output supplies of farm enterprises

$$(B.5) EY_{w1} = -(\lambda_{Yw2} * \tau_{Yw1,Yw2} + \lambda_{Yw3} * \tau_{Yw1,Yw3} + \lambda_{Yw4} * \tau_{Yw1,Yw4}) * EV_{w1} + \lambda_{Yw2} * \tau_{Yw1,Yw2} * EV_{w2} + \lambda_{Yw3} * \tau_{Yw1,Yw3} * EV_{w3} + \lambda_{Yw4} * \tau_{Yw1,Yw4} * EV_{w4} + EX^w$$

$$(B.6) EY_{w2} = -(\lambda_{Yw1} * \tau_{Yw1,Yw2} + \lambda_{Yw3} * \tau_{Yw2,Yw3} + \lambda_{Yw4} * \tau_{Yw2,Yw4}) * EV_{w2} + \lambda_{Yw1} * \tau_{Yw1,Yw2} * EV_{w1} + \lambda_{Yw3} * \tau_{Yw2,Yw3} * EV_{w3} + \lambda_{Yw4} * \tau_{Yw2,Yw4} * EV_{w4} + EX^w$$

$$(B.7) EY_{w3} = -(\lambda_{Yw1} * \tau_{Yw1,Yw3} + \lambda_{Yw2} * \tau_{Yw2,Yw3} + \lambda_{Yw4} * \tau_{Yw3,Yw4}) * EV_{w3} + \lambda_{Yw1} * \tau_{Yw1,Yw3} * EV_{w1} + \lambda_{Yw2} * \tau_{Yw2,Yw3} * EV_{w2} + \lambda_{Yw4} * \tau_{Yw3,Yw4} * EV_{w4} + EX^w$$

$$(B.8) EY_{w4} = -(\lambda_{Yw1} * \tau_{Yw1,Yw4} + \lambda_{Yw2} * \tau_{Yw2,Yw4} + \lambda_{Yw3} * \tau_{Yw3,Yw4}) * EV_{w4} + \lambda_{Yw1} * \tau_{Yw1,Yw4} * EV_{w1} + \lambda_{Yw2} * \tau_{Yw2,Yw4} * EV_{w2} + \lambda_{Yw3} * \tau_{Yw3,Yw4} * EV_{w3} + EX^w$$

1.4 Equilibrium conditions

$$(B.9) \kappa_{Xwv} * EX_{wv} + \kappa_{Xwo} * EX_{wo} = \lambda_{Yw1} * EY_{w1} + \lambda_{Yw2} * EY_{w2} + \lambda_{Yw3} * EY_{w3} + \lambda_{Yw4} * EY_{w4}$$

$$(B.10) \kappa_{Xwv} * EW_{wv} + \kappa_{Xwo} * EW_{wo} = \lambda_{Yw1} * EV_{w1} + \lambda_{Yw2} * EV_{w2} + \lambda_{Yw3} * EV_{w3} + \lambda_{Yw4} * EV_{w4}$$

2. Wheat Storage

2.1 Input supply to wheat storage

$$(B.11) EY_{w10} = \varepsilon_{Yw10,vw10} * (EV_{w10} - t_{Yw10})$$

2.2 Output constrained input demands of wheat storage

$$(B.12) EY_{w1} = -\kappa_{Yw10} * \sigma_{Yw1,Yw10} * EV_{w1} + \kappa_{Yw10} * \sigma_{Yw1,Yw10} * EV_{w10} + EZ^{ww}$$

$$(B.13) EY_{w10} = -\kappa_{Yw1} * \sigma_{Yw1,Yw10} * EV_{w10} + \kappa_{Yw1} * \sigma_{Yw1,Yw10} * EV_{w1} + EZ^{ww}$$

2.3 Input constrained output supply of wheat storage

$$(B.14) EZ_{w1} = -(\lambda_{Zw5} * \tau_{Zw1,Zw5} + \lambda_{Zw6} * \tau_{Zw1,Zw6}) * Eu_{w1} + \lambda_{Zw5} * \tau_{Zw1,Zw5} * Eu_{w5} + \lambda_{Zw6} * \tau_{Zw1,Zw6} * Eu_{w6} + EY^{ww}$$

$$(B.15) EZ_{w5} = -(\lambda_{Zw1} * \tau_{Zw1,Zw5} + \lambda_{Zw6} * \tau_{Zw5,Zw6}) * Eu_{w5} + \lambda_{Zw1} * \tau_{Zw1,Zw5} * Eu_{w1} + \lambda_{Zw6} * \tau_{Zw5,Zw6} * Eu_{w6} + EY^{ww}$$

$$(B.16) EZ_{w6} = -(\lambda_{Zw1} * \tau_{Zw1,Zw6} + \lambda_{Zw5} * \tau_{Zw5,Zw6}) * Eu_{w6} + \lambda_{Zw1} * \tau_{Zw1,Zw6} * Eu_{w1} + \lambda_{Zw5} * \tau_{Zw5,Zw6} * Eu_{w5} + EY^{ww}$$

2.4 Equilibrium conditions

$$(B.17) \kappa_{Yw1} * EY_{w1} + \kappa_{Yw10} * EY_{w10} = \lambda_{Zw1} * EZ_{w1} + \lambda_{Zw5} * EZ_{w5} + \lambda_{Zw6} * EZ_{w6}$$

$$(B.18) \kappa_{Vw1} * EV_{w1} + \kappa_{Vw10} * EV_{w10} = \lambda_{uw1} * Eu_{w1} + \lambda_{uw5} * Eu_{w5} + \lambda_{uw6} * Eu_{w6}$$

2.5 Export Demand

$$(B.19) EZ_{w1} = \eta_{Zw1,uw1} * (Eu_{w1} - n_{Zw1})$$

3. Barley Storage

3.1 Input supply to barley storage

$$(B.20) EY_{w20} = \varepsilon_{Yw20,vw20} * (EV_{w20} - t_{Yw20})$$

3.2 Output constrained input demands of barley storage

$$(B.21) EY_{w2} = -\kappa_{Yw20} * \sigma_{Yw2,Yw20} * EV_{w2} + \kappa_{Yw20} * \sigma_{Yw2,Yw20} * EV_{w20} + EZ^{wb}$$

$$(B.22) EY_{w20} = -\kappa_{Yw2} * \sigma_{Yw2,Yw20} * EV_{w20} + \kappa_{Yw2} * \sigma_{Yw2,Yw20} * EV_{w2} + EZ^{wb}$$

3.3 Input constrained output supply of barley storage

$$(B.23) EZ_{w2} = -(\lambda_{Zw7} * \tau_{Zw2,Zw7} + \lambda_{Zw8} * \tau_{Zw2,Zw8}) * Eu_{w2} + \lambda_{Zw7} * \tau_{Zw2,Zw7} * Eu_{w7} + \lambda_{Zw8} * \tau_{Zw2,Zw8} * Eu_{w8} + EY^{wb}$$

$$(B.24) EZ_{w7} = -(\lambda_{Zw2} * \tau_{Zw2,Zw7} + \lambda_{Zw8} * \tau_{Zw7,Zw8}) * Eu_{w7} + \lambda_{Zw2} * \tau_{Zw2,Zw7} * Eu_{w2} + \lambda_{Zw8} * \tau_{Zw7,Zw8} * Eu_{w8} + EY^{wb}$$

$$(B.25) EZ_{w8} = -(\lambda_{Zw2} * \tau_{Zw8,Zw2} + \lambda_{Zw7} * \tau_{Zw7,Zw8}) * Eu_{w8} + \lambda_{Zw2} * \tau_{Zw2,Zw8} * Eu_{w2} + \lambda_{Zw7} * \tau_{Zw7,Zw8} * Eu_{w7} + EY^{wb}$$

3.4 Equilibrium conditions

$$(B.26) \kappa_{Yw2} * EY_{w2} + \kappa_{Yw20} * EY_{w20} = \lambda_{Zw2} * EZ_{w2} + \lambda_{Zw7} * EZ_{w7} + \lambda_{Zw8} * EZ_{w8}$$

$$(B.27) \kappa_{Vw2} * EV_{w2} + \kappa_{Vw20} * EV_{w20} = \lambda_{uw2} * Eu_{w2} + \lambda_{uw7} * Eu_{w7} + \lambda_{uw8} * Eu_{w8}$$

3.5 Export Demand

$$(B.28) EZ_{w2} = \eta_{Zw2,uw2} * (Eu_{w2} - n_{Zw2})$$

4. Canola Storage

4.1 Input supply to canola storage

$$(B.29) EY_{w30} = \varepsilon_{Yw30,vw30} * (EV_{w30} - t_{Yw30})$$

4.2 Output constrained input demands of canola storage

$$(B.30) EY_{w3} = -\kappa_{Yw30} * \sigma_{Yw3,Yw30} * EV_{w3} + \kappa_{Yw30} * \sigma_{Yw3,Yw30} * EV_{w30} + EZ^{wc}$$

$$(B.31) EY_{w30} = -\kappa_{Yw3} * \sigma_{Yw3,Yw30} * EV_{w30} + \kappa_{Yw3} * \sigma_{Yw3,Yw30} * EV_{w3} + EZ^{wc}$$

4.3 Input constrained output supply of canola storage

$$(B.32) \quad EZ_{w3} = -\lambda_{Zw9} * \tau_{Zw3,Zw9} * Eu_{w3} + \lambda_{Zw9} * \tau_{Zw3,Zw9} * Eu_{w9} + EY^{wc}$$

$$(B.33) \quad EZ_{w9} = -\lambda_{Zw3} * \tau_{Zw3,Zw9} * Eu_{w9} + \lambda_{Zw3} * \tau_{Zw3,Zw9} * Eu_{w3} + EY^{wc}$$

4.4 Equilibrium conditions

$$(B.34) \quad \kappa_{Yw3} * EY_{w3} + \kappa_{Yw3o} * EY_{w3o} = \lambda_{Zw3} * EZ_{w3} + \lambda_{Zw9} * EZ_{w9}$$

$$(B.35) \quad \kappa_{Vw3} * EV_{w3} + \kappa_{Vw3o} * EV_{w3o} = \lambda_{uw3} * Eu_{w3} + \lambda_{uw9} * Eu_{w9}$$

4.5 Export Demand

$$(B.36) \quad EZ_{w3} = \eta_{Zw3,uw3} * (Eu_{w3} - n_{Zw3})$$

5. Lupin Storage**5.1 Input supply to lupin storage**

$$(B.37) \quad EY_{w4o} = \varepsilon_{Yw4o,vw4o} * (EV_{w4o} - t_{Yw4o})$$

5.2 Output constraints input demands of lupin storage

$$(B.38) \quad EY_{w4} = -\kappa_{Yw4o} * \sigma_{Yw4,Yw4o} * EV_{w4} + \kappa_{Yw4o} * \sigma_{Yw4,Yw4o} * EV_{w4o} + EZ^{wl}$$

$$(B.39) \quad EY_{w4o} = -\kappa_{Yw4} * \sigma_{Yw4,Yw4o} * EV_{w4o} + \kappa_{Yw4} * \sigma_{Yw4,Yw4o} * EV_{w4} + EZ^{wl}$$

5.3 Input constrained output supply of lupin storage

$$(B.40) \quad EZ_{w4} = -\lambda_{Zw10} * \tau_{Zw4,Zw10} * Eu_{w4} + \lambda_{Zw10} * \tau_{Zw4,Zw10} * Eu_{w10} + EY^{wl}$$

$$(B.41) \quad EZ_{w10} = -\lambda_{Zw4} * \tau_{Zw4,Zw10} * Eu_{w10} + \lambda_{Zw4} * \tau_{Zw4,Zw10} * Eu_{w4} + EY^{wl}$$

5.4 Equilibrium conditions

$$(B.42) \quad \kappa_{Yw4} * EY_{w4} + \kappa_{Yw4o} * EY_{w4o} = \lambda_{Zw4} * EZ_{w4} + \lambda_{Zw10} * EZ_{w10}$$

$$(B.43) \quad \kappa_{Vw4} * EV_{w4} + \kappa_{Vw4o} * EV_{w4o} = \lambda_{uw4} * Eu_{w4} + \lambda_{uw10} * Eu_{w10}$$

5.5 Export Demand

$$(B.44) \quad EZ_{w4} = \eta_{Zw4,uw4} * (Eu_{w4} - n_{Zw4})$$

6. Flour Milling**6.1 Input supply to flour milling**

$$(B.45) \quad EF_{w0} = \varepsilon_{Fw0,gw0} * (Eg_{w0} - t_{Fw0})$$

6.2 Output constrained input demand of flour milling

$$(B.46) \quad EZ_{w5} = -\kappa_{Fw0} * \sigma_{Zw5,Fw0} * Eu_{w5} + \kappa_{Fw0} * \sigma_{Zw5,Fw0} * Eg_{w0} + EF^w$$

$$(B.47) \quad EF_{w0} = -\kappa_{Zw5} * \sigma_{Zw5,Fw0} * Eg_{w0} + \kappa_{Zw5} * \sigma_{Zw5,Fw0} * Eu_{w5} + EF^w$$

6.3 Input constrained output supply of flour milling

$$(B.48) EF_{w1} = -\lambda_{FW2} * \tau_{FW1,FW2} * Eg_{w1} + \lambda_{FW2} * \tau_{FW1,FW2} * Eg_{w2} + EZ^{wf}$$

$$(B.49) EF_{w2} = -\lambda_{FW1} * \tau_{FW1,FW2} * Eg_{w2} + \lambda_{FW1} * \tau_{FW1,FW2} * Eg_{w1} + EZ^{wf}$$

6.4 Equilibrium conditions

$$(B.50) \kappa_{Zw5} * EZ_{w5} + \kappa_{FW0} * EF_{w0} = \lambda_{FW1} * EF_{w1} + \lambda_{FW2} * EF_{w2}$$

$$(B.51) \kappa_{uw5} * Eu_{w5} + \kappa_{gw0} * Eg_{w0} = \lambda_{gw1} * Eg_{w1} + \lambda_{gw2} * Eg_{w2}$$

6.5 Domestic demand

$$(B.52) EF_{w1} = \eta_{FW1,gw1} * (g_{w1} - n_{FW1})$$

7. Stockfeed Manufacturing**7.1 Input supply to stockfeed manufacturing**

$$(B.53) ES_{w0} = \varepsilon_{Swo,two} * (Et_{w0} - t_{Swo})$$

7.2 Output constrained input demand of stockfeed manufacturing

$$(B.54) EZ_{w6} = -(\kappa_{Zw7} * \sigma_{Zw6,Zw7} + \kappa_{Zw10} * \sigma_{Zw6,Zw10} + \kappa_{FW2} * \sigma_{Zw6,FW2} + \kappa_{Cw1} * \sigma_{Zw6,Cw1} + \kappa_{Swo} * \sigma_{Zw6,Swo}) * Eu_{w6} + \kappa_{Zw7} * \sigma_{Zw6,Zw7} * Eu_{w7} + \kappa_{Zw10} * \sigma_{Zw6,Zw10} * Eu_{w10} + \kappa_{FW2} * \sigma_{Zw6,FW2} * Eg_{w2} + \kappa_{Cw1} * \sigma_{Zw6,Cw1} * Ed_{w1} + \kappa_{Swo} * \sigma_{Zw6,Swo} * Et_{w0} + ES^w$$

$$(B.55) EZ_{w7} = -(\kappa_{Zw6} * \sigma_{Zw6,Zw7} + \kappa_{Zw10} * \sigma_{Zw7,Zw10} + \kappa_{FW2} * \sigma_{Zw7,FW2} + \kappa_{Cw1} * \sigma_{Zw7,Cw1} + \kappa_{Swo} * \sigma_{Zw7,Swo}) * Eu_{w7} + \kappa_{Zw6} * \sigma_{Zw6,Zw7} * Eu_{w6} + \kappa_{Zw10} * \sigma_{Zw7,Zw10} * Eu_{w10} + \kappa_{FW2} * \sigma_{Zw7,FW2} * Eg_{w2} + \kappa_{Cw1} * \sigma_{Zw7,Cw1} * Ed_{w1} + \kappa_{Swo} * \sigma_{Zw7,Swo} * Et_{w0} + ES^w$$

$$(B.56) EZ_{w10} = -(\kappa_{Zw6} * \sigma_{Zw6,Zw10} + \kappa_{Zw7} * \sigma_{Zw7,Zw10} + \kappa_{FW2} * \sigma_{Zw10,FW2} + \kappa_{Cw1} * \sigma_{Zw10,Cw1} + \kappa_{Swo} * \sigma_{Zw10,Swo}) * Eu_{w10} + \kappa_{Zw6} * \sigma_{Zw6,Zw10} * Eu_{w6} + \kappa_{Zw7} * \sigma_{Zw7,Zw10} * Eu_{w7} + \kappa_{FW2} * \sigma_{Zw10,FW2} * Eg_{w2} + \kappa_{Cw1} * \sigma_{Zw10,Cw1} * Ed_{w1} + \kappa_{Swo} * \sigma_{Zw10,Swo} * Et_{w0} + ES^w$$

$$(B.57) EF_{w2} = -(\kappa_{Zw6} * \sigma_{Zw6,FW2} + \kappa_{Zw7} * \sigma_{Zw7,FW2} + \kappa_{Zw10} * \sigma_{Zw10,FW2} + \kappa_{Cw1} * \sigma_{FW2,Cw1} + \kappa_{Swo} * \sigma_{FW2,Swo}) * Eg_{w2} + \kappa_{Zw6} * \sigma_{Zw6,FW2} * Eu_{w6} + \kappa_{Zw7} * \sigma_{Zw7,FW2} * Eu_{w7} + \kappa_{Zw10} * \sigma_{Zw10,FW2} * Eu_{w10} + \kappa_{Cw1} * \sigma_{FW2,Cw1} * Ed_{w1} + \kappa_{Swo} * \sigma_{FW2,Swo} * Et_{w0} + ES^w$$

$$(B.58) EC_{w1} = -(\kappa_{Zw6} * \sigma_{Zw6,Cw1} + \kappa_{Zw7} * \sigma_{Zw7,Cw1} + \kappa_{Zw10} * \sigma_{Zw10,Cw1} + \kappa_{FW2} * \sigma_{FW2,Cw1} + \kappa_{Swo} * \sigma_{Cw1,Swo}) * Ed_{w1} + \kappa_{Zw6} * \sigma_{Zw6,Cw1} * Eu_{w6} + \kappa_{Zw7} * \sigma_{Zw7,Cw1} * Eu_{w7} + \kappa_{Zw10} * \sigma_{Zw10,Cw1} * Eu_{w10} + \kappa_{FW2} * \sigma_{FW2,Cw1} * Eg_{w2} + \kappa_{Swo} * \sigma_{Cw1,Swo} * Et_{w0} + ES^w$$

$$(B.59) ES_{w0} = -(\kappa_{Zw6} * \sigma_{Zw6,Swo} + \kappa_{Zw7} * \sigma_{Zw7,Swo} + \kappa_{Zw10} * \sigma_{Zw10,Swo} + \kappa_{FW2} * \sigma_{FW2,Swo} + \kappa_{Cw1} * \sigma_{Cw1,Swo}) * Et_{w0} + \kappa_{Zw6} * \sigma_{Zw6,Swo} * Eu_{w6} + \kappa_{Zw7} * \sigma_{Zw7,Swo} * Eu_{w7} + \kappa_{Zw10} * \sigma_{Zw10,Swo} * Eu_{w10} + \kappa_{FW2} * \sigma_{FW2,Swo} * Eg_{w2} + \kappa_{Cw1} * \sigma_{Cw1,Swo} * Ed_{w1} + ES^w$$

7.3 Input constrained output supply of stockfeed manufacturing

$$(B.60) ES_{w1} = -\lambda_{Sw2} * \tau_{Sw1,Sw2} * Et_{w1} + \lambda_{Sw2} * \tau_{Sw1,Sw2} * Et_{w2} + EZ^{ws}$$

$$(B.61) ES_{w2} = -\lambda_{Sw1} * \tau_{Sw1,Sw2} * Et_{w2} + \lambda_{Sw1} * \tau_{Sw1,Sw2} * Et_{w1} + EZ^{ws}$$

7.4 Equilibrium conditions

$$(B.62) \kappa_{Zw6} * EZ_{w6} + \kappa_{Zw7} * EZ_{w7} + \kappa_{Zw10} * EZ_{w10} + \kappa_{Cw1} * EC_{w1} + \kappa_{FW2} * EF_{w2} + \kappa_{Swo} * ES_{w0} = \lambda_{Sw1} * ES_{w1} + \lambda_{Sw2} * ES_{w2}$$

$$(B.63) \kappa_{uw6} * Eu_{w6} + \kappa_{uw7} * Eu_{w7} + \kappa_{uw10} * Eu_{w10} + \kappa_{dw1} * Ed_{w1} + \kappa_{gw2} * Eg_{w2} + \kappa_{two} * Et_{wo} = \lambda_{tw1} * Et_{w1} + \lambda_{tw2} * Et_{w2}$$

7.5 Export demand

$$(B.64) ES_{w1} = \eta_{sw1,tw1} * (t_{w1} - n_{sw1})$$

7.6 Domestic demand

$$(B.65) ES_{w2} = \eta_{sw2,tw2} * (t_{w2} - n_{sw2})$$

8. Malt Manufacturing

8.1 Input supply to stockfeed manufacturing

$$(B.66) EM_{wo} = \varepsilon_{Mwo,nwo} * (En_{wo} - t_{Mwo})$$

8.2 Output constrained input demand of malt manufacturing

$$(B.67) EZ_{w8} = -\kappa_{Mwo} * \sigma_{Zw8,Mwo} * Eu_{w8} + \kappa_{Mwo} * \sigma_{Zw8,Mwo} * En_{wo} + EM^w$$

$$(B.68) EM_{wo} = -\kappa_{Zw8} * \sigma_{Zw8,Mwo} * En_{wo} + \kappa_{Zw8} * \sigma_{Zw8,Mwo} * Eu_{w8} + EM^w$$

8.3 Input constrained output supply of malt manufacturing

$$(B.69) EM_{w1} = -\lambda_{Mw2} * \tau_{Mw1,Mw2} * En_{w1} + \lambda_{Mw2} * \tau_{Mw1,Mw2} * En_{w2} + EZ^{wm}$$

$$(B.70) EM_{w2} = -\lambda_{Mw1} * \tau_{Mw1,Mw2} * En_{w2} + \lambda_{Mw1} * \tau_{Mw1,Mw2} * En_{w1} + EZ^{wm}$$

8.4 Equilibrium conditions

$$(B.71) \kappa_{Zw8} * EZ_{w8} + \kappa_{Mwo} * EM_{wo} = \lambda_{Mw1} * EM_{w1} + \lambda_{Mw2} * EM_{w2}$$

$$(B.72) \kappa_{uw8} * Eu_{w8} + \kappa_{nwo} * En_{wo} = \lambda_{nw1} * En_{w1} + \lambda_{nw2} * En_{w2}$$

8.5 Export demand

$$(B.73) EM_{w1} = \eta_{Mw1,tw1} * (t_{w1} - n_{Mw1})$$

8.6 Domestic demand

$$(B.74) EM_{w2} = \eta_{Mw2,tw2} * (t_{w2} - n_{Mw2})$$

9. Oilseed Crushing and Refining

9.1 Input supply to oilseed crushing and refining

$$(B.75) EC_{wo} = \varepsilon_{Cwo,dwo} * (Ed_{wo} - t_{Cwo})$$

9.2 Output constrained input demand of oilseed crushing and refining

$$(B.76) EZ_{w9} = -\kappa_{Cwo} * \sigma_{Zw9,Cwo} * Eu_{w9} + \kappa_{Cwo} * \sigma_{Zw9,Cwo} * Ed_{wo} + EC^w$$

$$(B.77) EC_{wo} = -\kappa_{Zw9} * \sigma_{Zw9,Cwo} * Ed_{wo} + \kappa_{Zw9} * \sigma_{Zw9,Cwo} * Eu_{w9} + EC^w$$

9.3 Input constrained output supply of oilseed crushing and refining

$$(B.78) EC_{w1} = -(\lambda_{Cw2} * \tau_{Cw1,Cw2} + \lambda_{Cw3} * \tau_{Cw1,Cw3}) * Ed_{w1} + \lambda_{Cw2} * \tau_{Cw1,Cw2} * Ed_{w2} + \lambda_{Cw3} * \tau_{Cw1,Cw3} * Ed_{w3} + EZ^{wc}$$

$$(B.79) \quad EC_{w2} = -(\lambda_{cw1} * \tau_{cw1,cw2} + \lambda_{cw3} * \tau_{cw2,cw3}) * Ed_{w2} + \lambda_{cw1} * \tau_{cw1,cw2} * Ed_{w1} + \lambda_{cw3} * \tau_{cw2,cw3} * Ed_{w3} + EZ^{wc}$$

$$(B.80) \quad EC_{w3} = -(\lambda_{cw1} * \tau_{cw1,cw3} + \lambda_{cw2} * \tau_{cw2,cw3}) * Ed_{w3} + \lambda_{cw1} * \tau_{cw1,cw3} * Ed_{w1} + \lambda_{cw2} * \tau_{cw2,cw3} * Ed_{w2} + EZ^{wc}$$

9.4 Equilibrium conditions

$$(B.81) \quad \kappa_{zw9} * EZ_{w9} + \kappa_{cwo} * EC_{wo} = \lambda_{cw1} * EC_{w1} + \lambda_{cw2} * EC_{w2}$$

$$(B.82) \quad \kappa_{uw9} * Eu_{w9} + \kappa_{dwo} * Ed_{wo} = \lambda_{dw1} * Ed_{w1} + \lambda_{dw2} * Ed_{w2}$$

9.5 Export demand

$$(B.83) \quad EC_{w2} = \eta_{cw2,dw2} * (d_{w2} - n_{cw2})$$

9.6 Domestic demand

$$(B.84) \quad EC_{w3} = \eta_{cw2,dw2} * (d_{w2} - n_{dw2})$$

Equilibrium Displacement Model of the Southern Region**1. Farm****1.1 Input supply to farm enterprises**

$$(B.85) EX_{sv} = \varepsilon_{Xsv, wsv} * (Ew_{sv} - t_{Xsv})$$

$$(B.86) EX_{so} = \varepsilon_{Xso, wso} * (Ew_{so} - t_{Xso})$$

1.2 Output constrained input demands of farm enterprises

$$(B.87) EX_{sv} = -\kappa_{Xso} * \sigma_{Xsv, Xso} * Ew_{sv} + \kappa_{Xso} * \sigma_{Xsv, Xso} * Ew_{so} + EY^s$$

$$(B.88) EX_{so} = -\kappa_{Xsv} * \sigma_{Xsv, Xso} * Ew_{so} + \kappa_{Xsv} * \sigma_{Xsv, Xso} * Ew_{sv} + EY^s$$

1.3 Input constrained output supplies of farm enterprises

$$(B.89) EY_{s1} = -(\lambda_{Ys2} * \tau_{Ys1, Ys2} + \lambda_{Ys3} * \tau_{Ys1, Ys3} + \lambda_{Ys4} * \tau_{Ys1, Ys4}) * Ev_{s1} + \lambda_{Ys2} * \tau_{Ys1, Ys2} * Ev_{s2} + \lambda_{Ys3} * \tau_{Ys1, Ys3} * Ev_{s3} + \lambda_{Ys4} * \tau_{Ys1, Ys4} * Ev_{s4} + EX^s$$

$$(B.90) EY_{s2} = -(\lambda_{Ys1} * \tau_{Ys1, Ys2} + \lambda_{Ys3} * \tau_{Ys2, Ys3} + \lambda_{Ys4} * \tau_{Ys2, Ys4}) * Ev_{s2} + \lambda_{Ys1} * \tau_{Ys1, Ys2} * Ev_{s1} + \lambda_{Ys3} * \tau_{Ys2, Ys3} * Ev_{s3} + \lambda_{Ys4} * \tau_{Ys2, Ys4} * Ev_{s4} + EX^s$$

$$(B.91) EY_{s3} = -(\lambda_{Ys1} * \tau_{Ys1, Ys3} + \lambda_{Ys2} * \tau_{Ys2, Ys3} + \lambda_{Ys4} * \tau_{Ys3, Ys4}) * Ev_{s3} + \lambda_{Ys1} * \tau_{Ys1, Ys3} * Ev_{s1} + \lambda_{Ys2} * \tau_{Ys2, Ys3} * Ev_{s2} + \lambda_{Ys4} * \tau_{Ys3, Ys4} * Ev_{s4} + EX^s$$

$$(B.92) EY_{s4} = -(\lambda_{Ys1} * \tau_{Ys1, Ys4} + \lambda_{Ys2} * \tau_{Ys2, Ys4} + \lambda_{Ys3} * \tau_{Ys3, Ys4}) * Ev_{s4} + \lambda_{Ys1} * \tau_{Ys1, Ys4} * Ev_{s1} + \lambda_{Ys2} * \tau_{Ys2, Ys4} * Ev_{s2} + \lambda_{Ys3} * \tau_{Ys3, Ys4} * Ev_{s3} + EX^s$$

1.4 Equilibrium conditions

$$(B.93) \kappa_{Xsv} * EX_{sv} + \kappa_{Xso} * EX_{so} = \lambda_{Ys1} * EY_{s1} + \lambda_{Ys2} * EY_{s2} + \lambda_{Ys3} * EY_{s3} + \lambda_{Ys4} * EY_{s4}$$

$$(B.94) \kappa_{Xsv} * Ew_{sv} + \kappa_{Xso} * Ew_{so} = \lambda_{Ys1} * Ev_{s1} + \lambda_{Ys2} * Ev_{s2} + \lambda_{Ys3} * Ev_{s3} + \lambda_{Ys4} * Ev_{s4}$$

2. Wheat Storage**2.1 Input supply to wheat storage**

$$(B.95) EY_{s10} = \varepsilon_{Ys10, vs10} * (Ev_{s10} - t_{Ys10})$$

2.2 Inter-regional wheat supply to wheat storage

$$(B.96) EY_{s5} = \varepsilon_{Ys5, vs5} * (Ev_{s5} - t_{Ys5})$$

2.3 Output constrained input demands of wheat storage

$$(B.97) EY_{s1} = -(\kappa_{Ys10} * \sigma_{Ys1, Ys10} + \kappa_{Ys5} * \sigma_{Ys1, Ys5}) * Ev_{s1} + \kappa_{Ys10} * \sigma_{Ys1, Ys10} * Ev_{s10} + \kappa_{Ys5} * \sigma_{Ys1, Ys5} * Ev_{s5} + EZ^{sw}$$

$$(B.98) EY_{s5} = -(\kappa_{Ys1} * \sigma_{Ys1, Ys5} + \kappa_{Ys10} * \sigma_{Ys5, Ys10}) * Ev_{s5} + \kappa_{Ys1} * \sigma_{Ys1, Ys5} * Ev_{s1} + \kappa_{Ys10} * \sigma_{Ys5, Ys10} * Ev_{s10} + EZ^{sw}$$

$$(B.99) EY_{s10} = -(\kappa_{Ys1} * \sigma_{Ys1, Ys10} + \kappa_{Ys5} * \sigma_{Ys5, Ys10}) * Ev_{s10} + \kappa_{Ys1} * \sigma_{Ys1, Ys10} * Ev_{s1} + \kappa_{Ys5} * \sigma_{Ys5, Ys10} * Ev_{s5} + EZ^{sw}$$

2.4 Input constrained output supply of wheat storage

$$(B.100) EZ_{s1} = -(\lambda_{Zs5} * \tau_{Zs1,Zs5} + \lambda_{Zs6} * \tau_{Zs1,Zs6}) * Eu_{s1} + \lambda_{Zs5} * \tau_{Zs1,Zs5} * Eu_{s5} + \lambda_{Zs6} * \tau_{Zs1,Zs6} * Eu_{s6} + EY^{sw}$$

$$(B.101) EZ_{s5} = -(\lambda_{Zs1} * \tau_{Zs1,Zs5} + \lambda_{Zs6} * \tau_{Zs5,Zs6}) * Eu_{s5} + \lambda_{Zs1} * \tau_{Zs1,Zs5} * Eu_{s1} + \lambda_{Zs6} * \tau_{Zs5,Zs6} * Eu_{s6} + EY^{sw}$$

$$(B.102) EZ_{s6} = -(\lambda_{Zs1} * \tau_{Zs1,Zs6} + \lambda_{Zs5} * \tau_{Zs5,Zs6}) * Eu_{s6} + \lambda_{Zs1} * \tau_{Zs1,Zs6} * Eu_{s1} + \lambda_{Zs5} * \tau_{Zs5,Zs6} * Eu_{s5} + EY^{sw}$$

2.5 Equilibrium conditions

$$(B.103) \kappa_{Ys1} * EY_{s1} + \kappa_{Ys5} * EY_{s5} + \kappa_{Ys10} * EY_{s10} = \lambda_{Zs1} * EZ_{s1} + \lambda_{Zs5} * EZ_{s5} + \lambda_{Zs6} * EZ_{s6}$$

$$(B.104) \kappa_{Vs1} * EV_{s1} + \kappa_{Vs5} * EV_{s5} + \kappa_{Vs10} * EV_{s10} = \lambda_{us1} * Eu_{s1} + \lambda_{us5} * Eu_{s5} + \lambda_{us6} * Eu_{s6}$$

2.6 Export demand

$$(B.105) EZ_{s1} = \eta_{Zs1,us1} * (Eu_{s1} - n_{Zs1})$$

3. Barley Storage**3.1 Input supply to barley storage**

$$(B.106) EY_{s20} = \varepsilon_{Ys20,vs20} * (EV_{s20} - t_{Ys20})$$

3.2 Inter-regional barley supply to barley storage

$$(B.107) EY_{s6} = \varepsilon_{Ys6,vs6} * (EV_{s6} - t_{Ys6})$$

3.3 Output constrained input demands of barley storage

$$(B.108) EY_{s2} = -(\kappa_{Ys20} * \sigma_{Ys2,Ys20} + \kappa_{Ys6} * \sigma_{Ys2,Ys6}) * EV_{s2} + \kappa_{Ys20} * \sigma_{Ys2,Ys20} * EV_{s20} + \kappa_{Ys6} * \sigma_{Ys2,Ys6} * EV_{s6} + EZ^{sb}$$

$$(B.109) EY_6 = -(\kappa_{Ys2} * \sigma_{Ys2,Ys6} + \kappa_{Ys20} * \sigma_{Ys6,Ys20}) * EV_{s6} + \kappa_{Ys2} * \sigma_{Ys2,Ys6} * EV_{s2} + \kappa_{Ys20} * \sigma_{Ys6,Ys20} * EV_{s20} + EZ^{sb}$$

$$(B.110) EY_{s20} = -(\kappa_{Ys2} * \sigma_{Ys2,Ys20} + \kappa_{Ys6} * \sigma_{Ys6,Ys20}) * EV_{s20} + \kappa_{Ys2} * \sigma_{Ys2,Ys20} * EV_{s2} + \kappa_{Ys6} * \sigma_{Ys6,Ys20} * EV_{s6} + EZ^{sb}$$

3.4 Input constrained output supply of barley storage

$$(B.111) EZ_{s2} = -(\lambda_{Zs7} * \tau_{Zs2,Zs7} + \lambda_{Zs8} * \tau_{Zs2,Zs8}) * Eu_{s2} + \lambda_{Zs7} * \tau_{Zs2,Zs7} * Eu_{s7} + \lambda_{Zs8} * \tau_{Zs2,Zs8} * Eu_{s8} + EY^{sb}$$

$$(B.112) EZ_{s7} = -(\lambda_{Zs2} * \tau_{Zs2,Zs7} + \lambda_{Zs8} * \tau_{Zs7,Zs8}) * Eu_{s7} + \lambda_{Zs2} * \tau_{Zs2,Zs7} * Eu_{s2} + \lambda_{Zs8} * \tau_{Zs7,Zs8} * Eu_{s8} + EY^{sb}$$

$$(B.113) EZ_{s8} = -(\lambda_{Zs2} * \tau_{Zs2,Zs8} + \lambda_{Zs7} * \tau_{Zs7,Zs8}) * Eu_{s8} + \lambda_{Zs2} * \tau_{Zs2,Zs8} * Eu_{s2} + \lambda_{Zs7} * \tau_{Zs7,Zs8} * Eu_{s7} + EY^{sb}$$

3.5 Equilibrium conditions

$$(B.114) \kappa_{Ys2} * EY_{s2} + \kappa_{Ys6} * EY_{s6} + \kappa_{Ys20} * EY_{s20} = \lambda_{Zs2} * EZ_{s2} + \lambda_{Zs7} * EZ_{s7} + \lambda_{Zs8} * EZ_{s8}$$

$$(B.115) \kappa_{Vs2} * EV_{s2} + \kappa_{Vs6} * EV_{s6} + \kappa_{Vs20} * EV_{s20} = \lambda_{us2} * Eu_{s2} + \lambda_{us7} * Eu_{s7} + \lambda_{us8} * Eu_{s8}$$

3.6 Export demand

$$(B.116) EZ_{s2} = \eta_{Zs2,us2} * (Eu_{s2} - n_{Zs2})$$

4. Canola Storage**4.1 Input supply to canola storage**

$$(B.117) EY_{s30} = \varepsilon_{Ys30,vs30} * (Ev_{s30} - t_{Ys30})$$

4.2 Inter-regional canola supply to canola storage

$$(B.118) EY_{s7} = \varepsilon_{Ys7,vs7} * (Ev_{s7} - t_{Ys7})$$

4.3 Output constrained input demands of canola storage

$$(B.119) EY_{s3} = -(k_{Ys30} * \sigma_{Ys3,Ys30} + k_{Ys7} * \sigma_{Ys3,Ys7}) * Ev_{s3} + k_{Ys30} * \sigma_{Ys3,Ys30} * Ev_{s30} + k_{Ys7} * \sigma_{Ys3,Ys7} * Ev_{s7} + EZ^{sc}$$

$$(B.120) EY_{s7} = -(k_{Ys3} * \sigma_{Ys3,Ys7} + k_{Ys30} * \sigma_{Ys7,Ys30}) * Ev_{s7} + k_{Ys3} * \sigma_{Ys3,Ys7} * Ev_{s3} + k_{Ys30} * \sigma_{Ys7,Ys30} * Ev_{s30} + EZ^{sc}$$

$$(B.121) EY_{s30} = -(k_{Ys3} * \sigma_{Ys3,Ys30} + k_{Ys7} * \sigma_{Ys7,Ys30}) * Ev_{s30} + k_{Ys3} * \sigma_{Ys3,Ys30} * Ev_{s3} + k_{Ys7} * \sigma_{Ys7,Ys30} * Ev_{s7} + EZ^{sc}$$

4.4 Input constrained output supply of canola storage

$$(B.122) EZ_{s3} = -\lambda_{Zs9} * \tau_{Zs3,Zs9} * Eu_{s3} + \lambda_{Zs9} * \tau_{Zs3,Zs9} * Eu_{s9} + EY^{sc}$$

$$(B.123) EZ_{s9} = -\lambda_{Zs3} * \tau_{Zs3,Zs9} * Eu_{s9} + \lambda_{Zs3} * \tau_{Zs3,Zs9} * Eu_{s3} + EY^{sc}$$

4.5 Equilibrium conditions

$$(B.124) k_{Ys3} * EY_{s3} + k_{Ys7} * EY_{s7} + k_{Ys30} * EY_{s30} = \lambda_{Zs3} * EZ_{s3} + \lambda_{Zs9} * EZ_{s9}$$

$$(B.125) k_{vs3} * Ev_{s3} + k_{vs7} * Ev_{s7} + k_{vs30} * Ev_{s30} = \lambda_{us3} * Eu_{s3} + \lambda_{us9} * Eu_{s9}$$

4.6 Export demand

$$(B.126) EZ_{s3} = \eta_{Zs3,us3} * (Eu_{s3} - n_{Zs3})$$

5. Lupin Storage**5.1 Input supply to lupin storage**

$$(B.127) EY_{s40} = \varepsilon_{Ys40,vs40} * (Ev_{s40} - t_{Ys40})$$

5.2 Output constraints input demands of lupin storage

$$(B.128) EY_{s4} = -k_{Ys40} * \sigma_{Ys4,Ys40} * Ev_{s4} + k_{Ys40} * \sigma_{Ys4,Ys40} * Ev_{s40} + EZ^{sl}$$

$$(B.129) EY_{s40} = -k_{Ys4} * \sigma_{Ys4,Ys40} * Ev_{s40} + k_{Ys4} * \sigma_{Ys4,Ys40} * Ev_{s4} + EZ^{sl}$$

5.3 Input constrained output supply of lupin storage

$$(B.130) EZ_{s4} = -\lambda_{Zs10} * \tau_{Zs4,Zs10} * Eu_{s4} + \lambda_{Zs10} * \tau_{Zs4,Zs10} * Eu_{s10} + EY^{sl}$$

$$(B.131) EZ_{s10} = -\lambda_{Zs4} * \tau_{Zs4,Zs10} * Eu_{s10} + \lambda_{Zs4} * \tau_{Zs4,Zs10} * Eu_{s4} + EY^{sl}$$

5.4 Equilibrium conditions

$$(B.132) k_{Ys4} * EY_{s4} + k_{Ys40} * EY_{s40} = \lambda_{Zs4} * EZ_{s4} + \lambda_{Zs10} * EZ_{s10}$$

$$(B.133) k_{vs4} * Ev_{s4} + k_{vs40} * Ev_{s40} = \lambda_{us4} * Eu_{s4} + \lambda_{us10} * Eu_{s10}$$

5.5 Export Demand

$$(B.134) \text{EZ}_{s4} = \eta_{Zs4,us4} * (\text{Eu}_{s4} - n_{Zs4})$$

6. Flour Milling**6.1 Input supply to flour milling**

$$(B.135) \text{EF}_{so} = \varepsilon_{Fso,gso} * (\text{Eg}_{so} - t_{Fso})$$

6.2 Output constrained input demand of flour milling

$$(B.136) \text{EZ}_{s5} = -\kappa_{Fso} * \sigma_{Zs5,Fso} * \text{Eu}_{s5} + \kappa_{Fso} * \sigma_{Zs5,Fso} * \text{Eg}_{so} + \text{EF}^s$$

$$(B.137) \text{EF}_{so} = -\kappa_{Zs5} * \sigma_{Zs5,Fso} * \text{Eg}_{so} + \kappa_{Zs5} * \sigma_{Zs5,Fso} * \text{Eu}_{s5} + \text{EF}^s$$

6.3 Input constrained output supply of flour milling

$$(B.138) \text{EF}_{s1} = -\lambda_{Fs2} * \tau_{Fs1,Fs2} * \text{Eg}_{s1} + \lambda_{Fs2} * \tau_{Fs1,Fs2} * \text{Eg}_{s2} + \text{EZ}^{sf}$$

$$(B.139) \text{EF}_{s2} = -\lambda_{Fs1} * \tau_{Fs1,Fs2} * \text{Eg}_{s2} + \lambda_{Fs1} * \tau_{Fs1,Fs2} * \text{Eg}_{s1} + \text{EZ}^{sf}$$

6.4 Equilibrium conditions

$$(B.140) \kappa_{Zs5} * \text{EZ}_{s5} + \kappa_{Fso} * \text{EF}_{so} = \lambda_{Fs1} * \text{EF}_{s1} + \lambda_{Fs2} * \text{EF}_{s2}$$

$$(B.141) \kappa_{us5} * \text{Eu}_{s5} + \kappa_{gso} * \text{Eg}_{so} = \lambda_{gs1} * \text{Eg}_{s1} + \lambda_{gs2} * \text{Eg}_{s2}$$

6.5 Domestic demand

$$(B.142) \text{EF}_{s1} = \eta_{Fs1,gs1} * (g_{s1} - n_{Fs1})$$

7. Stockfeed Manufacturing**7.1 Input supply to stockfeed manufacturing**

$$(B.143) \text{ES}_{so} = \varepsilon_{Sso,tso} * (\text{Et}_{so} - t_{Sso})$$

7.2 Output constrained input demand of stockfeed manufacturing

$$(B.144) \text{EZ}_{s6} = -(\kappa_{Zs7} * \sigma_{Zs6,Zs7} + \kappa_{Zs10} * \sigma_{Zs6,Zs10} + \kappa_{Fs2} * \sigma_{Zs6,Fs2} + \kappa_{Cs1} * \sigma_{Zs6,Cs1} + \kappa_{Sso} * \sigma_{Zs6,Sso}) * \text{Eu}_{s6} + \kappa_{Zs7} * \sigma_{Zs6,Zs7} * \text{Eu}_{s7} + \kappa_{Zs10} * \sigma_{Zs6,Zs10} * \text{Eu}_{s10} + \kappa_{Fs2} * \sigma_{Zs6,Fs2} * \text{Eg}_{s2} + \kappa_{Cs1} * \sigma_{Zs6,Cs1} * \text{Ed}_{s1} + \kappa_{Sso} * \sigma_{Zs6,Sso} * \text{Et}_{so} + \text{ES}^s$$

$$(B.145) \text{EZ}_{s7} = -(\kappa_{Zs6} * \sigma_{Zs6,Zs7} + \kappa_{Zs10} * \sigma_{Zs7,Zs10} + \kappa_{Fs2} * \sigma_{Zs7,Fs2} + \kappa_{Cs1} * \sigma_{Zs7,Cs1} + \kappa_{Sso} * \sigma_{Zs7,Sso}) * \text{Eu}_{s7} + \kappa_{Zs6} * \sigma_{Zs6,Zs7} * \text{Eu}_{s6} + \kappa_{Zs10} * \sigma_{Zs7,Zs10} * \text{Eu}_{s10} + \kappa_{Fs2} * \sigma_{Zs7,Fs2} * \text{Eg}_{s2} + \kappa_{Cs1} * \sigma_{Zs7,Cs1} * \text{Ed}_{s1} + \kappa_{Sso} * \sigma_{Zs7,Sso} * \text{Et}_{so} + \text{ES}^s$$

$$(B.146) \text{EZ}_{s10} = -(\kappa_{Zs6} * \sigma_{Zs6,Zs10} + \kappa_{Zs7} * \sigma_{Zs7,Zs10} + \kappa_{Fs2} * \sigma_{Zs10,Fs2} + \kappa_{Cs1} * \sigma_{Zs10,Cs1} + \kappa_{Sso} * \sigma_{Zs10,Sso}) * \text{Eu}_{s10} + \kappa_{Zs6} * \sigma_{Zs6,Zs10} * \text{Eu}_{s6} + \kappa_{Zs7} * \sigma_{Zs7,Zs10} * \text{Eu}_{s7} + \kappa_{Fs2} * \sigma_{Zs10,Fs2} * \text{Eg}_{s2} + \kappa_{Cs1} * \sigma_{Zs10,Cs1} * \text{Ed}_{s1} + \kappa_{Sso} * \sigma_{Zs10,Sso} * \text{Et}_{so} + \text{ES}^s$$

$$(B.147) EF_{s2} = -(\kappa_{Zs6} * \sigma_{Zs6,Fs2} + \kappa_{Zs7} * \sigma_{Zs7,Fs2} + \kappa_{Zs10} * \sigma_{Zs10,Fs2} + \kappa_{Cs1} * \sigma_{Fs2,Cs1} + \kappa_{Sso} * \sigma_{Fs2,Sso}) * Eg_{s2} + \kappa_{Zs6} * \sigma_{Zs6,Fs2} * Eu_{s6} + \kappa_{Zs7} * \sigma_{Zs7,Fs2} * Eu_{s7} + \kappa_{Zs10} * \sigma_{Zs10,Fs2} * Eu_{s10} + \kappa_{Cs1} * \sigma_{Fs2,Cs1} * Ed_{s1} + \kappa_{Sso} * \sigma_{Fs2,Sso} * Et_{so} + ES^s$$

$$(B.148) EC_{s1} = -(\kappa_{Zs6} * \sigma_{Zs6,Cs1} + \kappa_{Zs7} * \sigma_{Zs7,Cs1} + \kappa_{Zs10} * \sigma_{Zs10,Cs1} + \kappa_{Fs2} * \sigma_{Fs2,Cs1} + \kappa_{Sso} * \sigma_{Cs1,Sso}) * Ed_{s1} + \kappa_{Zs6} * \sigma_{Zs6,Cs1} * Eu_{s6} + \kappa_{Zs7} * \sigma_{Zs7,Cs1} * Eu_{s7} + \kappa_{Zs10} * \sigma_{Zs10,Cs1} * Eu_{s10} + \kappa_{Fs2} * \sigma_{Fs2,Cs1} * Eg_{s2} + \kappa_{Sso} * \sigma_{Cs1,Sso} * Et_{so} + ES^s$$

$$(A149) ES_{so} = -(\kappa_{Zs6} * \sigma_{Zs6,Sso} + \kappa_{Zs7} * \sigma_{Zs7,Sso} + \kappa_{Zs10} * \sigma_{Zs10,Sso} + \kappa_{Fs2} * \sigma_{Fs2,Sso} + \kappa_{Cs1} * \sigma_{Cs1,Sso}) * Et_{so} + \kappa_{Zs6} * \sigma_{Zs6,Sso} * Eu_{s6} + \kappa_{Zs7} * \sigma_{Zs7,Sso} * Eu_{s7} + \kappa_{Zs10} * \sigma_{Zs10,Sso} * Eu_{s10} + \kappa_{Fs2} * \sigma_{Fs2,Sso} * Eg_{s2} + \kappa_{Cs1} * \sigma_{Cs1,Sso} * Ed_{s1} + ES^s$$

7.3 Input constrained output supply of stockfeed manufacturing

$$(B.150) ES_{s1} = -\lambda_{Ss2} * \tau_{Ss1,Ss2} * Et_{s1} + \lambda_{Ss2} * \tau_{Ss1,Ss2} * Et_{s2} + EZ^{ss}$$

$$(B.151) ES_{s2} = -\lambda_{Ss1} * \tau_{Ss1,Ss2} * Et_{s2} + \lambda_{Ss1} * \tau_{Ss1,Ss2} * Et_{s1} + EZ^{ss}$$

7.4 Equilibrium conditions

$$(B.152) \kappa_{Zs6} * EZ_{s6} + \kappa_{Zs7} * EZ_{s7} + \kappa_{Zs10} * EZ_{s10} + \kappa_{Cs1} * EC_{s1} + \kappa_{Fs2} * EF_{s2} + \kappa_{Sso} * ES_{so} = \lambda_{Ss1} * ES_{s1} + \lambda_{Ss2} * ES_{s2}$$

$$(B.153) \kappa_{us6} * Eu_{s6} + \kappa_{us7} * Eu_{s7} + \kappa_{us10} * Eu_{s10} + \kappa_{ds1} * Ed_{s1} + \kappa_{gs2} * Eg_{s2} + \kappa_{tso} * Et_{so} = \lambda_{ts1} * Et_{s1} + \lambda_{ts2} * Et_{s2}$$

7.5 Export demand

$$(B.154) ES_{s1} = \eta_{Ss1,ts1} * (t_{s1} - n_{Ss1})$$

7.6 Domestic demand

$$(B.155) ES_{s2} = \eta_{Ss2,ts2} * (t_{s2} - n_{Ss2})$$

8. Malt Manufacturing

8.1 Input supply to stockfeed manufacturing

$$(B.156) EM_{so} = \epsilon_{Mso,nso} * (En_{so} - t_{Mso})$$

8.2 Output constrained input demand of malt manufacturing

$$(B.157) EZ_{s8} = -\kappa_{Mso} * \sigma_{Zs8,Mso} * Eu_{s8} + \kappa_{Mso} * \sigma_{Zs8,Mso} * En_{so} + EM^s$$

$$(B.158) EM_{so} = -\kappa_{Zs8} * \sigma_{Zs8,Mso} * En_{so} + \kappa_{Zs8} * \sigma_{Zs8,Mso} * Eu_{s8} + EM^s$$

8.3 Input constrained output supply of malt manufacturing

$$(B.159) EM_{s1} = -\lambda_{Ms2} * \tau_{Ms1,Ms2} * En_{s1} + \lambda_{Ms2} * \tau_{Ms1,Ms2} * En_{s2} + EZ^{sm}$$

$$(B.160) EM_{s2} = -\lambda_{Ms1} * \tau_{Ms1,Ms2} * En_{s2} + \lambda_{Ms1} * \tau_{Ms1,Ms2} * En_{s1} + EZ^{sm}$$

8.4 Equilibrium conditions

$$(B.161) \kappa_{Zs8} * EZ_{s8} + \kappa_{Mso} * EM_{so} = \lambda_{Ms1} * EM_{s1} + \lambda_{Ms2} * EM_{s2}$$

$$(B.162) \kappa_{us8} * Eu_{s8} + \kappa_{nso} * En_{so} = \lambda_{ns1} * En_{s1} + \lambda_{ns2} * En_{s2}$$

8.5 Export demand

$$(B.163) EM_{s1} = \eta_{Ms1,ts1} * (t_{s1} - n_{Ms1})$$

8.6 Domestic demand

$$(B.164) \text{EM}_{s2} = \eta_{Ms2,ts2} * (t_{s2} - n_{Ms2})$$

9. Oilseed Crushing and Refining**9.1 Input supply to oilseed crushing and refining**

$$(B.165) \text{EC}_{s0} = \varepsilon_{Cs0,dso} * (\text{Ed}_{s0} - t_{Cs0})$$

9.2 Output constrained input demand of oilseed crushing and refining

$$(B.166) \text{EZ}_{s9} = -\kappa_{Cs0} * \sigma_{Zs9,Cs0} * \text{Eu}_{s9} + \kappa_{Cs0} * \sigma_{Zs9,Cs0} * \text{Ed}_{s0} + \text{EC}^s$$

$$(B.167) \text{EC}_{s0} = -\kappa_{Zs9} * \sigma_{Zs9,Cs0} * \text{Ed}_{s0} + \kappa_{Zs9} * \sigma_{Zs9,Cs0} * \text{Eu}_{s9} + \text{EC}^s$$

9.3 Input constrained output supply of oilseed crushing and refining

$$(B.168) \text{EC}_{s1} = -(\lambda_{Cs2} * \tau_{Cs1,Cs2} + \lambda_{Cs3} * \tau_{Cs1,Cs3}) * \text{Ed}_{s1} + \lambda_{Cs2} * \tau_{Cs1,Cs2} * \text{Ed}_{s2} + \lambda_{Cs3} * \tau_{Cs1,Cs3} * \text{Ed}_{s3} + \text{EZ}^{sc}$$

$$(B.169) \text{EC}_{s2} = -(\lambda_{Cs1} * \tau_{Cs1,Cs2} + \lambda_{Cs3} * \tau_{Cs2,Cs3}) * \text{Ed}_{s2} + \lambda_{Cs1} * \tau_{Cs1,Cs2} * \text{Ed}_{s1} + \lambda_{Cs3} * \tau_{Cs2,Cs3} * \text{Ed}_{s3} + \text{EZ}^{sc}$$

$$(B.170) \text{EC}_{s3} = -(\lambda_{Cs1} * \tau_{Cs1,Cs3} + \lambda_{Cs2} * \tau_{Cs2,Cs3}) * \text{Ed}_{s3} + \lambda_{Cs1} * \tau_{Cs1,Cs3} * \text{Ed}_{s1} + \lambda_{Cs2} * \tau_{Cs2,Cs3} * \text{Ed}_{s2} + \text{EZ}^{sc}$$

9.4 Equilibrium conditions

$$(B.171) \kappa_{Zs9} * \text{EZ}_{s9} + \kappa_{Cs0} * \text{EC}_{s0} = \lambda_{Cs1} * \text{EC}_{s1} + \lambda_{Cs2} * \text{EC}_{s2}$$

$$(B.172) \kappa_{us9} * \text{Eu}_{s9} + \kappa_{dso} * \text{Ed}_{s0} = \lambda_{ds1} * \text{Ed}_{s1} + \lambda_{ds2} * \text{Ed}_{s2}$$

9.5 Export demand

$$(B.173) \text{EC}_{s2} = \eta_{Cs2,ds2} * (d_{s2} - n_{Cs2})$$

9.6 Domestic demand

$$(B.174) \text{EC}_{s3} = \eta_{Cs2,ds2} * (d_{s2} - n_{ds2})$$

Equilibrium Displacement Model of the Northern Region

1. Farm

1.1 Input supply to farm enterprises

$$(B.175) EX_{nv} = \varepsilon_{Xnv,wnv} * (EW_{nv} - t_{Xnv})$$

$$(B.176) EX_{no} = \varepsilon_{Xno,wno} * (EW_{no} - t_{Xno})$$

1.2 Output constrained input demands of farm enterprises

$$(B.177) EX_{nv} = -\kappa_{Xno} * \sigma_{Xnv,Xno} * EW_{nv} + \kappa_{Xno} * \sigma_{Xnv,Xno} * EW_{no} + EY^n$$

$$(B.178) EX_{no} = -\kappa_{Xnv} * \sigma_{Xnv,Xno} * EW_{no} + \kappa_{Xnv} * \sigma_{Xnv,Xno} * EW_{nv} + EY^n$$

1.3 Input constrained output supplies of farm enterprises

$$(B.179) EY_{n1} = -(\lambda_{Yn2} * \tau_{Yn1,Yn2} + \lambda_{Yn3} * \tau_{Yn1,Yn3} + \lambda_{Yn4} * \tau_{Yn1,Yn4}) * EV_{n1} + \lambda_{Yn2} * \tau_{Yn1,Yn2} * EV_{n2} + \lambda_{Yn3} * \tau_{Yn1,Yn3} * EV_{n3} + \lambda_{Yn4} * \tau_{Yn1,Yn4} * EV_{n4} + EX^n$$

$$(B.180) EY_{n2} = -(\lambda_{Yn1} * \tau_{Yn1,Yn2} + \lambda_{Yn3} * \tau_{Yn2,Yn3} + \lambda_{Yn4} * \tau_{Yn2,Yn4}) * EV_{n2} + \lambda_{Yn1} * \tau_{Yn1,Yn2} * EV_{n1} + \lambda_{Yn3} * \tau_{Yn2,Yn3} * EV_{n3} + \lambda_{Yn4} * \tau_{Yn2,Yn4} * EV_{n4} + EX^n$$

$$(B.181) EY_{n3} = -(\lambda_{Yn1} * \tau_{Yn1,Yn3} + \lambda_{Yn2} * \tau_{Yn2,Yn3} + \lambda_{Yn4} * \tau_{Yn3,Yn4}) * EV_{n3} + \lambda_{Yn1} * \tau_{Yn1,Yn3} * EV_{n1} + \lambda_{Yn2} * \tau_{Yn2,Yn3} * EV_{n2} + \lambda_{Yn4} * \tau_{Yn3,Yn4} * EV_{n4} + EX^n$$

$$(B.182) EY_{n4} = -(\lambda_{Yn1} * \tau_{Yn1,Yn4} + \lambda_{Yn2} * \tau_{Yn2,Yn4} + \lambda_{Yn3} * \tau_{Yn3,Yn4}) * EV_{n4} + \lambda_{Yn1} * \tau_{Yn1,Yn4} * EV_{n1} + \lambda_{Yn2} * \tau_{Yn2,Yn4} * EV_{n2} + \lambda_{Yn3} * \tau_{Yn3,Yn4} * EV_{n3} + EX^n$$

1.4 Equilibrium conditions

$$(B.183) \kappa_{Xnv} * EX_{nv} + \kappa_{Xno} * EX_{no} = \lambda_{Yn1} * EY_{n1} + \lambda_{Yn2} * EY_{n2} + \lambda_{Yn3} * EY_{n3} + \lambda_{Yn4} * EY_{n4}$$

$$(B.184) \kappa_{Xnv} * EN_{nv} + \kappa_{Xno} * EN_{no} = \lambda_{Yn1} * EV_{n1} + \lambda_{Yn2} * EV_{n2} + \lambda_{Yn3} * EV_{n3} + \lambda_{Yn4} * EV_{n4}$$

2. Wheat Storage

2.1 Input supply to wheat storage

$$(B.185) EY_{s10} = \varepsilon_{Yn10,vn10} * (EV_{n10} - t_{Yn10})$$

2.2 Output constrained input demands of wheat storage

$$(B.186) EY_{n1} = -\kappa_{Yn10} * \sigma_{Yn1,Yn10} * EV_{n1} + \kappa_{Yn10} * \sigma_{Yn1,Yn10} * EV_{n10} + EZ^{nw}$$

$$(B.187) EY_{n10} = -\kappa_{Yn1} * \sigma_{Yn10,Yn1} * EV_{n10} + \kappa_{Yn1} * \sigma_{Yn10,Yn1} * EV_{n1} + EZ^{nw}$$

2.3 Input constrained output supply of wheat storage

$$(B.188) EZ_{n1} = -(\lambda_{Zn5} * \tau_{Zn1,Zn5} + \lambda_{Zn6} * \tau_{Zn1,Zn6} + \lambda_{Zn11} * \tau_{Zn1,Zn11}) * EU_{n1} + \lambda_{Zn5} * \tau_{Zn1,Zn5} * EU_{n5} + \lambda_{Zn6} * \tau_{Zn1,Zn6} * EU_{n6} + \lambda_{Zn11} * \tau_{Zn1,Zn11} * EU_{n11} + EY^{nw}$$

$$(B.189) EZ_{n5} = -(\lambda_{Zn1} * \tau_{Zn1,Zn5} + \lambda_{Zn6} * \tau_{Zn5,Zn6} + \lambda_{Zn11} * \tau_{Zn5,Zn11}) * EU_{n5} + \lambda_{Zn1} * \tau_{Zn1,Zn5} * EU_{n1} + \lambda_{Zn6} * \tau_{Zn5,Zn6} * EU_{n6} + \lambda_{Zn11} * \tau_{Zn5,Zn11} * EU_{n11} + EY^{nw}$$

$$(B.190) EZ_{n6} = -(\lambda_{Zn1} * \tau_{Zn1,Zn6} + \lambda_{Zn5} * \tau_{Zn5,Zn6} + \lambda_{Zn11} * \tau_{Zn6,Zn11}) * EU_{n6} + \lambda_{Zn1} * \tau_{Zn1,Zn6} * EU_{n1} + \lambda_{Zn5} * \tau_{Zn5,Zn6} * EU_{n5} + \lambda_{Zn11} * \tau_{Zn6,Zn11} * EU_{n11} + EY^{nw}$$

$$(B.191) EZ_{n11} = -(\lambda_{Zn1} * \tau_{Zn1,Zn11} + \lambda_{Zn5} * \tau_{Zn5,Zn11} + \lambda_{Zn6} * \tau_{Zn6,Zn11}) * EU_{n11} + \lambda_{Zn1} * \tau_{Zn1,Zn11} * EU_{n1} + \lambda_{Zn5} * \tau_{Zn5,Zn11} * EU_{n5} + \lambda_{Zn6} * \tau_{Zn6,Zn11} * EU_{n6} + EY^{nw}$$

2.4 Equilibrium conditions

$$(B.192) \kappa_{Yn1} * EY_{n1} + \kappa_{Yn1o} * EY_{n1o} = \lambda_{Zn1} * EZ_{n1} + \lambda_{Zn5} * EZ_{n5} + \lambda_{Zn6} * EZ_{n6} + \lambda_{Zn11} * EZ_{n11}$$

$$(B.193) \kappa_{vn1} * EV_{n1} + \kappa_{vn1o} * EV_{n1o} = \lambda_{un1} * Eu_{n1} + \lambda_{un5} * Eu_{n5} + \lambda_{un6} * Eu_{n6} + \lambda_{un11} * Eu_{n11}$$

2.5 Export demand

$$(B.194) EZ_{n1} = \eta_{Zn1,un1} * (Eu_{n1} - n_{Zn1})$$

2.5 Domestic demand from other region

$$(B.195) EZ_{11} = \eta_{Zn11,un11} * (Eu_{n11} - n_{Zn11})$$

3. Barley Storage**3.1 Input supply to barley storage**

$$(B.196) EY_{n2o} = \varepsilon_{Yn2o,vn2o} * (EV_{n2o} - t_{Yn2o})$$

3.2 Output constrained input demands of barley storage

$$(B.197) EY_{n2} = -\kappa_{Yn2o} * \sigma_{Yn2,Yn2o} * EV_{n2} + \kappa_{Yn2o} * \sigma_{Yn2,Yn2o} * EV_{n2o} + EZ^{nb}$$

$$(B.198) EY_{n2o} = -\kappa_{Yn2} * \sigma_{Yn2,Yn2o} * EV_{n2o} + \kappa_{Yn2} * \sigma_{Yn2,Yn2o} * EV_{n2} + EZ^{nb}$$

3.3 Input constrained output supply of barley storage

$$(B.199) EZ_{n2} = -(\lambda_{Zn7} * \tau_{Zn2,Zn7} + \lambda_{Zn8} * \tau_{Zn2,Zn8} + \lambda_{Zn12} * \tau_{Zn2,Zn12}) * Eu_{n2} + \lambda_{Zn7} * \tau_{Zn2,Zn7} * Eu_{n7} + \lambda_{Zn8} * \tau_{Zn2,Zn8} * Eu_{n8} + \lambda_{Zn12} * \tau_{Zn2,Zn12} * Eu_{n12} + EY^{nb}$$

$$(B.200) EZ_{n7} = -(\lambda_{Zn2} * \tau_{Zn2,Zn7} + \lambda_{Zn8} * \tau_{Zn7,Zn8} + \lambda_{Zn12} * \tau_{Zn7,Zn12}) * Eu_{n7} + \lambda_{Zn2} * \tau_{Zn2,Zn7} * Eu_{n2} + \lambda_{Zn8} * \tau_{Zn7,Zn8} * Eu_{n8} + \lambda_{Zn12} * \tau_{Zn7,Zn12} * Eu_{n12} + EY^{nb}$$

$$(B.201) EZ_{n8} = -(\lambda_{Zn2} * \tau_{Zn2,Zn8} + \lambda_{Zn7} * \tau_{Zn7,Zn8} + \lambda_{Zn12} * \tau_{Zn8,Zn12}) * Eu_{n8} + \lambda_{Zn2} * \tau_{Zn2,Zn8} * Eu_{n2} + \lambda_{Zn7} * \tau_{Zn7,Zn8} * Eu_{n7} + \lambda_{Zn12} * \tau_{Zn8,Zn12} * Eu_{n12} + EY^{nb}$$

$$(B.202) EZ_{n12} = -(\lambda_{Zn2} * \tau_{Zn2,Zn12} + \lambda_{Zn7} * \tau_{Zn7,Zn12} + \lambda_{Zn8} * \tau_{Zn8,Zn12}) * Eu_{n12} + \lambda_{Zn2} * \tau_{Zn2,Zn12} * Eu_{n2} + \lambda_{Zn7} * \tau_{Zn7,Zn12} * Eu_{n7} + \lambda_{Zn8} * \tau_{Zn8,Zn12} * Eu_{n8} + EY^{nb}$$

3.4 Equilibrium conditions

$$(B.203) \kappa_{Yn2} * EY_{n2} + \kappa_{Yn2o} * EY_{n2o} = \lambda_{Zn2} * EZ_{n2} + \lambda_{Zn7} * EZ_{n7} + \lambda_{Zn8} * EZ_{n8} + \lambda_{Zn12} * EZ_{n12}$$

$$(B.204) \kappa_{vn2} * EV_{n2} + \kappa_{vn2o} * EV_{n2o} = \lambda_{un2} * Eu_{n2} + \lambda_{un7} * Eu_{n7} + \lambda_{un8} * Eu_{n8} + \lambda_{un12} * Eu_{n12}$$

3.5 Export demand

$$(B.205) EZ_{n2} = \eta_{Zn2,un2} * (Eu_{n2} - n_{Zn2})$$

3.5 Demand from other region

$$(B.206) EZ_{n12} = \eta_{Zn12,un12} * (Eu_{n2} - n_{Zn12})$$

4. Canola Storage

4.1 Input supply to canola storage

$$(B.207) EY_{n3o} = \varepsilon_{Yn3o, vn3o} * (Ev_{n3o} - t_{Yn3o})$$

4.2 Output constrained input demands of canola storage

$$(B.208) EY_{n3} = -\kappa_{Yn3o} * \sigma_{Yn3, Yn3o} * Ev_{n3} + \kappa_{Yn3o} * \sigma_{Yn3, Yn3o} * Ev_{n3o} + EZ^{nc}$$

$$(B.209) EY_{n3o} = -\kappa_{Yn3} * \sigma_{Yn3, Yn3o} * Ev_{n3o} + \kappa_{Yn3} * \sigma_{Yn3, Yn3o} * Ev_{n3} + EZ^{nc}$$

4.3 Input constrained output supply of canola storage

$$(B.210) EZ_{n3} = -(\lambda_{Zn9} * \tau_{Zn3, Zn9} + \lambda_{Zn13} * \tau_{Zn3, Zn13}) * Eu_{n3} + \lambda_{Zn9} * \tau_{Zn3, Zn9} * Eu_{n9} + \lambda_{Zn13} * \tau_{Zn3, Zn13} * Eu_{n13} + EY^{nc}$$

$$(B.211) EZ_{n9} = -(\lambda_{Zn3} * \tau_{Zn3, Zn9} + \lambda_{Zn13} * \tau_{Zn9, Zn13}) * Eu_{n9} + \lambda_{Zn3} * \tau_{Zn3, Zn9} * Eu_{n3} + \lambda_{Zn13} * \tau_{Zn9, Zn13} * Eu_{n13} + EY^{nc}$$

$$(B.212) EZ_{n13} = -(\lambda_{Zn3} * \tau_{Zn3, Zn13} + \lambda_{Zn9} * \tau_{Zn9, Zn13}) * Eu_{n13} + \lambda_{Zn3} * \tau_{Zn3, Zn13} * Eu_{n3} + \lambda_{Zn9} * \tau_{Zn9, Zn13} * Eu_{n9} + EY^{nc}$$

4.4 Equilibrium conditions

$$(B.213) \kappa_{Yn3} * EY_{n3} + \kappa_{Yn3o} * EY_{n3o} = \lambda_{Zn3} * EZ_{n3} + \lambda_{Zn9} * EZ_{n9} + \lambda_{Zn13} * EZ_{n13}$$

$$(B.214) \kappa_{vn3} * Ev_{n3} + \kappa_{vn3o} * Ev_{n3o} = \lambda_{un3} * Eu_{n3} + \lambda_{un9} * Eu_{n9} + \lambda_{un13} * Eu_{n13}$$

4.5 Export demand

$$(B.215) EZ_{n3} = \eta_{Zn3, un3} * (Eu_{n3} - n_{Zn3})$$

4.5 Demand from other region

$$(B.216) EZ_{n3} = \eta_{Zn3, un3} * (Eu_{n3} - n_{Zn3})$$

5. Lupin Storage

5.1 Input supply to lupin storage

$$(B.217) EY_{n4o} = \varepsilon_{Yn4o, vn4o} * (Ev_{n4o} - t_{Yn4o})$$

5.2 Output constraints input demands of lupin storage

$$(B.218) EY_{n4} = -\kappa_{Yn4o} * \sigma_{Yn4, Yn4o} * Ev_{n4} + \kappa_{Yn4o} * \sigma_{Yn4, Yn4o} * Ev_{n4o} + EZ^{nl}$$

$$(B.219) EY_{n4o} = -\kappa_{Yn4} * \sigma_{Yn4, Yn4o} * Ev_{n4o} + \kappa_{Yn4} * \sigma_{Yn4, Yn4o} * Ev_{n4} + EZ^{nl}$$

5.3 Input constrained output supply of lupin storage

$$(B.220) EZ_{n4} = -\lambda_{Zn10} * \tau_{Zn4, Zn10} * Eu_{n4} + \lambda_{Zn10} * \tau_{Zn4, Zn10} * Eu_{n10} + EY^{nl}$$

$$(B.221) EZ_{n10} = -\lambda_{Zn4} * \tau_{Zn4, Zn10} * Eu_{n10} + \lambda_{Zn4} * \tau_{Zn4, Zn10} * Eu_{n4} + EY^{nl}$$

5.4 Equilibrium conditions

$$(B.222) \kappa_{Yn4} * EY_{n4} + \kappa_{Yn4o} * EY_{n4o} = \lambda_{Zn4} * EZ_{n4} + \lambda_{Zn10} * EZ_{n10}$$

$$(B.223) \kappa_{vn4} * Ev_{n4} + \kappa_{vn4o} * Ev_{n4o} = \lambda_{un4} * Eu_{n4} + \lambda_{un10} * Eu_{n10}$$

5.5 Export Demand

$$(B.224) \quad EZ_{n4} = \eta_{zn4,un4} * (Eu_{n4} - n_{zn4})$$

6. Flour Milling**6.1 Input supply to flour milling**

$$(B.225) \quad EF_{no} = \varepsilon_{Fno,gno} * (Eg_{no} - t_{Fno})$$

6.2 Output constrained input demand of flour milling

$$(B.226) \quad EZ_{n5} = -\kappa_{Fno} * \sigma_{zn5,Fno} * Eu_{n5} + \kappa_{Fno} * \sigma_{zn5,Fno} * Eg_{no} + EF^n$$

$$(B.227) \quad EF_{no} = -\kappa_{zn5} * \sigma_{zn5,Fno} * Eg_{no} + \kappa_{zn5} * \sigma_{zn5,Fno} * Eu_{n5} + EF^n$$

6.3 Input constrained output supply of flour milling

$$(B.228) \quad EF_{n1} = -\lambda_{Fn2} * \tau_{Fn1,Fn2} * Eg_{n1} + \lambda_{Fn2} * \tau_{Fn1,Fn2} * Eg_{n2} + EZ^{nf}$$

$$(B.229) \quad EF_{n2} = -\lambda_{Fn1} * \tau_{Fn1,Fn2} * Eg_{n2} + \lambda_{Fn1} * \tau_{Fn1,Fn2} * Eg_{n1} + EZ^{nf}$$

6.4 Equilibrium conditions

$$(B.230) \quad \kappa_{zn5} * EZ_{n5} + \kappa_{Fno} * EF_{no} = \lambda_{Fn1} * EF_{n1} + \lambda_{Fn2} * EF_{n2}$$

$$(B.231) \quad \kappa_{un5} * Eu_{n5} + \kappa_{gno} * Eg_{no} = \lambda_{gn1} * Eg_{n1} + \lambda_{gn2} * Eg_{n2}$$

6.5 Domestic demand

$$(B.232) \quad EF_{n1} = \eta_{Fn1,gn1} * (g_{n1} - n_{Fn1})$$

7. Stockfeed Manufacturing**7.1 Input supply to stockfeed manufacturing**

$$(B.233) \quad ES_{no} = \varepsilon_{Sno,tno} * (Et_{no} - t_{Sno})$$

7.2 Output constrained input demand of stockfeed manufacturing

$$(B.234) \quad EZ_{n6} = -(\kappa_{zn7} * \sigma_{zn6,zn7} + \kappa_{zn10} * \sigma_{zn6,zn10} + \kappa_{Fn2} * \sigma_{zn6,Fn2} + \kappa_{Cn1} * \sigma_{zn6,Cn1} + \kappa_{Sno} * \sigma_{zn6,Sno}) * Eu_{n6} + \kappa_{zn7} * \sigma_{zn6,zn7} * Eu_{n7} + \kappa_{zn10} * \sigma_{zn6,zn10} * Eu_{n10} + \kappa_{Fn2} * \sigma_{zn6,Fn2} * Eg_{n2} + \kappa_{Cn1} * \sigma_{zn6,Cn1} * Ed_{n1} + \kappa_{Sno} * \sigma_{zn6,Sno} * Et_{no} + ES^n$$

$$(B.235) \quad EZ_{n7} = -(\kappa_{zn6} * \sigma_{zn6,zn7} + \kappa_{zn10} * \sigma_{zn7,zn10} + \kappa_{Fn2} * \sigma_{zn7,Fn2} + \kappa_{Cn1} * \sigma_{zn7,Cn1} + \kappa_{Sno} * \sigma_{zn7,Sno}) * Eu_{n7} + \kappa_{zn6} * \sigma_{zn6,zn7} * Eu_{n6} + \kappa_{zn10} * \sigma_{zn7,zn10} * Eu_{n10} + \kappa_{Fn2} * \sigma_{zn7,Fn2} * Eg_{n2} + \kappa_{Cn1} * \sigma_{zn7,Cn1} * Ed_{n1} + \kappa_{Sno} * \sigma_{zn7,Sno} * Et_{no} + ES^n$$

$$(B.236) \quad EZ_{n10} = -(\kappa_{zn6} * \sigma_{zn6,zn10} + \kappa_{zn7} * \sigma_{zn7,zn10} + \kappa_{Fn2} * \sigma_{zn10,Fn2} + \kappa_{Cn1} * \sigma_{zn10,Cn1} + \kappa_{Sno} * \sigma_{zn10,Sno}) * Eu_{n10} + \kappa_{zn6} * \sigma_{zn6,zn10} * Eu_{n6} + \kappa_{zn7} * \sigma_{zn7,zn10} * Eu_{n7} + \kappa_{Fn2} * \sigma_{zn10,Fn2} * Eg_{n2} + \kappa_{Cn1} * \sigma_{zn10,Cn1} * Ed_{n1} + \kappa_{Sno} * \sigma_{zn10,Sno} * Et_{no} + ES^n$$

$$(B.237) EF_{n2} = -(\kappa_{Zn6} * \sigma_{Zn6,Fn2} + \kappa_{Zn7} * \sigma_{Zn7,Fn2} + \kappa_{Zn10} * \sigma_{Zw10,Fn2} + \kappa_{Cn1} * \sigma_{Fn2,Cn1} + \kappa_{Sno} * \sigma_{Fn2,Sno}) * Eg_{n2} + \kappa_{Zn6} * \sigma_{Zn6,Fn2} * Eu_{n6} + \kappa_{Zn7} * \sigma_{Zn7,Fn2} * Eu_{n7} + \kappa_{Zn10} * \sigma_{Zw10,Fn2} * Eu_{n10} + \kappa_{Cn1} * \sigma_{Fn2,Cn1} * Ed_{n1} + \kappa_{Sno} * \sigma_{Fn2,Sno} * Et_{no} + ES^n$$

$$(B.238) EC_{n1} = -(\kappa_{Zn6} * \sigma_{Zn6,Cn1} + \kappa_{Zn7} * \sigma_{Zn7,Cn1} + \kappa_{Zn10} * \sigma_{Zn10,Cn1} + \kappa_{Fn2} * \sigma_{Fn2,Cn1} + \kappa_{Sno} * \sigma_{Cn1,Sno}) * Ed_{n1} + \kappa_{Zn6} * \sigma_{Zn6,Cn1} * Eu_{n6} + \kappa_{Zn7} * \sigma_{Zn7,Cn1} * Eu_{n7} + \kappa_{Zn10} * \sigma_{Zn10,Cn1} * Eu_{n10} + \kappa_{Fn2} * \sigma_{Fn2,Cn1} * Eg_{n2} + \kappa_{Sno} * \sigma_{Cn1,Sno} * Et_{no} + ES^n$$

$$(B.239) ES_{no} = -(\kappa_{Zn6} * \sigma_{Zn6,Sno} + \kappa_{Zn7} * \sigma_{Zn7,Sno} + \kappa_{Zn10} * \sigma_{Zn10,Sno} + \kappa_{Fn2} * \sigma_{Fn2,Sno} + \kappa_{Cn1} * \sigma_{Cn1,Sno}) * Et_{no} + \kappa_{Zn6} * \sigma_{Zn6,Sno} * Eu_{n6} + \kappa_{Zn7} * \sigma_{Zn7,Sno} * Eu_{n7} + \kappa_{Zn10} * \sigma_{Zn10,Sno} * Eu_{n10} + \kappa_{Fn2} * \sigma_{Fn2,Sno} * Et_{no} + \kappa_{Cn1} * \sigma_{Cn1,Sno} * Ed_{n1} + ES^n$$

7.3 Input constrained output supply of stockfeed manufacturing

$$(B.240) ES_{n1} = -\lambda_{Sn2} * \tau_{Sn1,Sn2} * Et_{n1} + \lambda_{Sn2} * \tau_{Sn1,Sn2} * Et_{n2} + EZ^{ns}$$

$$(B.241) ES_{n2} = -\lambda_{Sn1} * \tau_{Sn2,Sn1} * Et_{n2} + \lambda_{Sn1} * \tau_{Sn2,Sn1} * Et_{n1} + EZ^{ns}$$

7.4 Equilibrium conditions

$$(B.242) \kappa_{Zn6} * EZ_{n6} + \kappa_{Zn7} * EZ_{n7} + \kappa_{Zn10} * EZ_{n10} + \kappa_{Cn1} * EC_{n1} + \kappa_{Fn2} * EF_{n2} + \kappa_{Sno} * ES_{no} = \lambda_{Sn1} * ES_{n1} + \lambda_{Sn2} * ES_{n2}$$

$$(B.243) \kappa_{un6} * Eu_{n6} + \kappa_{un7} * Eu_{n7} + \kappa_{un10} * Eu_{n10} + \kappa_{dn1} * Ed_{n1} + \kappa_{gn2} * Eg_{n2} + \kappa_{tno} * Et_{no} = \lambda_{tn1} * Et_{n1} + \lambda_{tn2} * Et_{n2}$$

7.5 Export demand

$$(B.244) ES_{n1} = \eta_{Sn1,tn1} * (t_{n1} - n_{Sn1})$$

7.6 Domestic demand

$$(B.245) ES_{n2} = \eta_{Sn2,tn2} * (t_{n2} - n_{Sn2})$$

8. Malt Manufacturing

8.1 Input supply to stockfeed manufacturing

$$(B.246) EM_{no} = \varepsilon_{Mno, nno} * (En_{no} - t_{Mno})$$

8.2 Output constrained input demand of malt manufacturing

$$(B.247) EZ_{n8} = -\kappa_{Mno} * \sigma_{Zn8,Mno} * Eu_{n8} + \kappa_{Mno} * \sigma_{Zn8,Mno} * En_{no} + EM^n$$

$$(B.248) EM_{no} = -\kappa_{Zn8} * \sigma_{Zn8,Mno} * En_{no} + \kappa_{Zn8} * \sigma_{Zn8,Mno} * Eu_{n8} + EM^n$$

8.3 Input constrained output supply of malt manufacturing

$$(B.249) EM_{n1} = -\lambda_{Mn2} * \tau_{Mn1,Mn2} * En_{n1} + \lambda_{Mn2} * \tau_{Mn1,Mn2} * En_{n2} + EZ^{nm}$$

$$(B.250) EM_{n2} = -\lambda_{Mn1} * \tau_{Mn1,Mn2} * En_{n2} + \lambda_{Mn1} * \tau_{Mn1,Mn2} * En_{n1} + EZ^{nm}$$

8.4 Equilibrium conditions

$$(B.251) \kappa_{Zn8} * EZ_{n8} + \kappa_{Mno} * EM_{no} = \lambda_{Mn1} * EM_{n1} + \lambda_{Mn2} * EM_{n2}$$

$$(B.252) \kappa_{un8} * Eu_{n8} + \kappa_{nno} * En_{no} = \lambda_{nn1} * En_{n1} + \lambda_{nn2} * En_{n2}$$

8.5 Export demand

$$(B.253) EM_{n1} = \eta_{Mn1,tn1} * (t_{n1} - n_{Mn1})$$

8.6 Domestic demand

$$(B.254) EM_{n2} = \eta_{Mn2,tn2} * (t_{n2} - n_{Mn2})$$

9. Oilseed Crushing and Refining**9.1 Input supply to oilseed crushing and refining**

$$(B.255) EC_{no} = \varepsilon_{Cno,dno} * (Ed_{no} - t_{Cno})$$

9.2 Output constrained input demand of oilseed crushing and refining

$$(B.256) EZ_{n9} = -\kappa_{Cno} * \sigma_{Zn9,Cno} * Eu_{n9} + \kappa_{Cno} * \sigma_{Zn9,Cno} * Ed_{no} + EC^n$$

$$(B.257) EC_{no} = -\kappa_{Zn9} * \sigma_{Zn9,Cno} * Ed_{no} + \kappa_{Zn9} * \sigma_{Zn9,Cno} * Eu_{n9} + EC^n$$

9.3 Input constrained output supply of oilseed crushing and refining

$$(B.258) EC_{n1} = -(\lambda_{Cn2} * \tau_{Cn1,Cn2} + \lambda_{Cn3} * \tau_{Cn1,Cn3}) * Ed_{n1} + \lambda_{Cn2} * \tau_{Cn1,Cn2} * Ed_{n2} + \lambda_{Cn3} * \tau_{Cn1,Cn3} * Ed_{n3} + EZ^{nc}$$

$$(B.259) EC_{n2} = -(\lambda_{Cn1} * \tau_{Cn1,Cn2} + \lambda_{Cn3} * \tau_{Cn2,Cn3}) * Ed_{n2} + \lambda_{Cn1} * \tau_{Cn1,Cn2} * Ed_{n1} + \lambda_{Cn3} * \tau_{Cn2,Cn3} * Ed_{n3} + EZ^{nc}$$

$$(B.260) EC_{n3} = -(\lambda_{Cn1} * \tau_{Cn1,Cn3} + \lambda_{Cn2} * \tau_{Cn2,Cn3}) * Ed_{n3} + \lambda_{Cn1} * \tau_{Cn1,Cn3} * Ed_{n1} + \lambda_{Cn2} * \tau_{Cn2,Cn3} * Ed_{n2} + EZ^{nc}$$

9.4 Equilibrium conditions

$$(B.261) \kappa_{Zn9} * EZ_{w9} + \kappa_{Cno} * EC_{no} = \lambda_{Cw1} * EC_{n1} + \lambda_{Cw2} * EC_{n2}$$

$$(B.262) \kappa_{un9} * Eu_{w9} + \kappa_{dno} * Ed_{no} = \lambda_{dw1} * Ed_{n1} + \lambda_{dw2} * Ed_{n2}$$

9.5 Export demand

$$(B.263) EC_{n2} = \eta_{Cn2,dn2} * (d_{n2} - n_{Cn2})$$

9.6 Domestic demand

$$(B.264) EC_{n3} = \eta_{Cn2,dn2} * (d_{n2} - n_{dn2})$$