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Impacts of changes in consumption, production and trade policies in China and India on trade and greenhouse gases emissions, particularly in New Zealand

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Meike Guenther

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Abstract of a thesis submitted in partial fulfilment of the requirements for the Degree of Master of Applied Science.

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by

Meike Guenther

Population growth, urbanisation and rising incomes are changing the level and composition of food consumption in emerging countries. In India and China particularly, this development is accompanied by shifts in dietary patterns away from staples towards more livestock products. However, livestock production has been identified as a large contributor to climate change. Changes in China and India's consumption and production patterns are likely to affect other countries by altering their agricultural production, food consumption and trade of agricultural commodities, as well as greenhouse gases (GHG) emissions from their livestock sector. An additional important consideration for producers and exporters concerns the reduction of international trade barriers that may lead to changing patterns of global agricultural production and trade. This may also affect the total amount of GHG emissions from changing levels of livestock production. New Zealand is a small open economy heavily dependent on agricultural exports. Therefore, changes in consumer diets and regulatory trade policies in China and India may have implications for domestic consumption, production and trade as well as agricultural GHG emissions in New Zealand.

The main objectives of this thesis are to assess the potential impacts of changes in meat and dairy consumption and production, as well as different trade policies in China and India, on New Zealand trade and GHG emissions from agricultural commodities. The analytical approach employs the Lincoln Trade and Environment Model (LTEM), a partial equilibrium model that forecasts international trade, production and consumption of agricultural commodities, and GHG emissions from livestock production. A number of scenarios were developed simulating different ranges of consumption and production of meat and dairy commodities in China and India as well as full trade liberalisation in both countries.

For New Zealand, some of the most significant results suggested that producer returns from beef and skim milk powder were predicted to increase significantly if India and China were to partially adopt US dietary patterns. However, the associated effect of these changes was a moderate increase in GHG emissions from the beef and dairy sector. In contrast, if China and India would significantly increase meat and dairy consumption and production by relatively large growth rates that are evenly distributed across all commodities, New Zealand producer returns particularly from the dairy sector were predicted to fall as a consequence of both declines in dairy prices and production. In turn, this would lead to a decrease in GHG emissions from dairy in New Zealand following decreased production. Full trade liberalisation in China and India was predicted to increase producer returns in New Zealand across all meat and dairy commodities but would also slightly increase GHG emissions from livestock. Results from this thesis are important for policy makers when negotiating further trade policies with India and China, as well as national and international climate policies.

Keywords: meat and dairy consumption, meat and dairy production, trade liberalisation, partial equilibrium model, agricultural GHG emissions, China, India, New Zealand

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List of Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ASEAN	Association of Southeast Asian Nations
CH_4	Methane
CAPSiM	Chinese Agricultural Policy's Agricultural Policy Simulation and Projection Model
CGE	Computable general equilibrium
CO_2	Carbon dioxide
CO_2 – equ.	Carbon dioxide – equivalents
ERS	Economic Research Service of US Department of Agriculture
ESIM	European Simulation Model
NZ ETS	New Zealand Emissions Trading Scheme
FAO	Food and Agriculture Organization of the United Nations
FAPRI	Food and Agricultural Policy Research Institute
GAPsi	Gemeinsame Agrar Politik Simulation
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GE	General equilibrium
GHG	Greenhouse gases
GLS	Grain Livestock and Sugar Model
GTAP	Global Trade Analysis Project
GWP	Global Warming Potential
IAM	Integrated Assessment Models
IFPRI	International Food Policy Research Institute
IMAGE	Integrated Model to Assess the Global Environment
IMF	International Monetary Fund
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IPCC	Intergovernmental Panel on Climate Change
LTEM	Lincoln Trade and Environment Model
MAgPIE	Model of Agricultural Production and its Impact on the Environment
MTM	Ministerial Trade Mandate
N_2O	Nitrous oxide
NZ	New Zealand
OECD	Organisation for Economic Co-operation and Development

p.a.	per annum
PE	Partial equilibrium
SMP	Skim milk powder
SWOPSIM	Static World Policy Simulation Model
TRQ	Tariff rate quota
UAE	United Arab Emirates
US	United States of America
USDA	United States Department of Agriculture
VORSIM	Vernon Oley Roningen Simulation Model
WATSIM	World Agricultural Trade Simulation Model
WMP	Whole milk powder
WTO	World Trade Organization

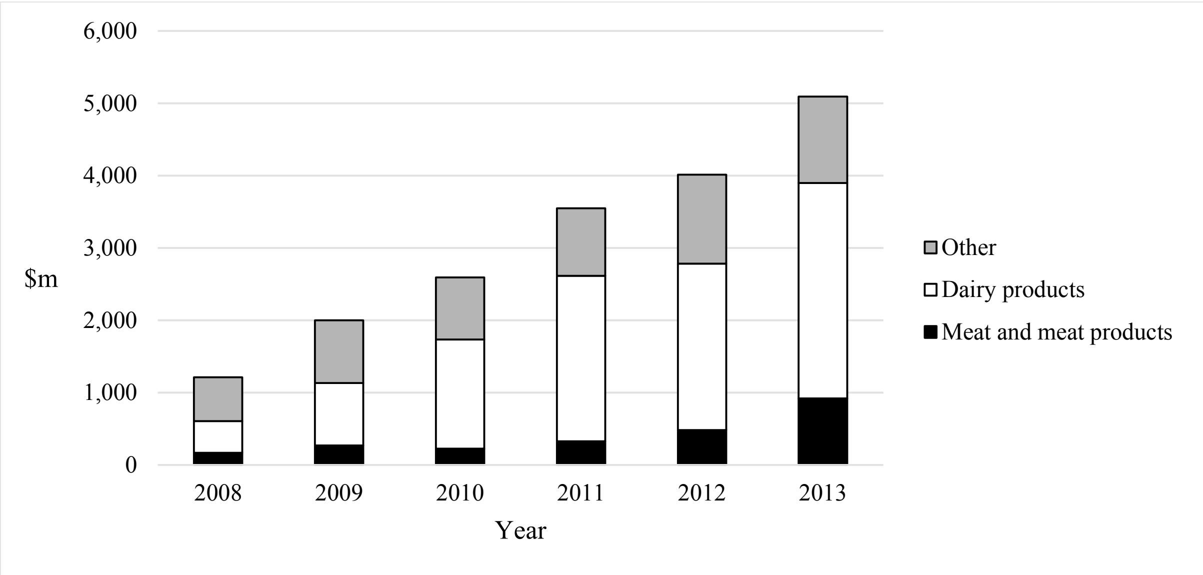
Chapter 1
Introduction

The level of food consumption has been increasing globally and is driven by a growing population, urbanisation and rising incomes in developing countries. In China and India, the growth in food consumption is accompanied by a shift in dietary patterns away from staples towards more livestock products such as meat and dairy products and vegetable oils (Food and Agriculture Organization of the United Nations [FAO], 2006; 2012a; 2012b).

Food consumption has been identified as one of the key issues contributing to high energy use and environmental pollution from production processes (e.g., Marlow, Hayes, Soret, Carter, Schwab & Sabaté, 2009; Carlsson-Kanyama & Gonzalez, 2009; Baroni, Cenci, Tettamanti & Berati, 2007; Brower & Leon, 1999). In particular, livestock production has been identified as a large contributor to climate change (Steinfeld, Gerber, Wassenaar, Castel, Rosales & de Haan, 2006). Within the agricultural sector, livestock production is one of the largest sources of greenhouse gases (GHG) with a large share coming from ruminant animals with enteric fermentation and manure management as the most polluting components (FAO, 2009; Steinfeld et al., 2006). These impacts are expected to grow in the future, especially with an increased demand for livestock products (Steinfeld et al., 2006).

New Zealand is a small open economy which is heavily dependent on its agricultural exports particularly from the meat and dairy sector (Statistics New Zealand [SNZ], 2013). Historically, the UK was New Zealand's key export market taking almost all exports until the 1960's. However, in recent years trade with developing countries such as China and India has grown in importance for New Zealand. Both countries are emerging export markets for New Zealand and exports to these countries have grown steadily. China has been New Zealand's key export market for agricultural commodities since 2010. As shown in Figure 1.1, agricultural exports to China more than quadrupled between 2008 and 2013, accounting for an increase of NZ$3.8 billion. In this period, the highest growth was recorded for dairy exports which increased 6-fold, and in 2013 China took 24 per cent of all New Zealand dairy exports (SNZ, 2013). In addition, exports of meat commodities have increased 5-fold between 2008 and 2013, and in 2013 China took 16 per cent of all New Zealand meat exports (SNZ, 2013). In particular, sheep meat exports increased more than 7-times between 2008 and 2013 (SNZ, 2010; 2013). The increase in trade flows between New Zealand and China may have been facilitated by the Free Trade Agreement (FTA) between the two countries which came into force in 2008 with tariff reductions still ongoing. The FTA liberalises and facilitates trade in goods, services and investment between the two countries and will be fully implemented in 2019. New Zealand was the first OECD economy to sign a FTA with China (Ministry of Foreign Affairs and Trade [MFAT], 2008).

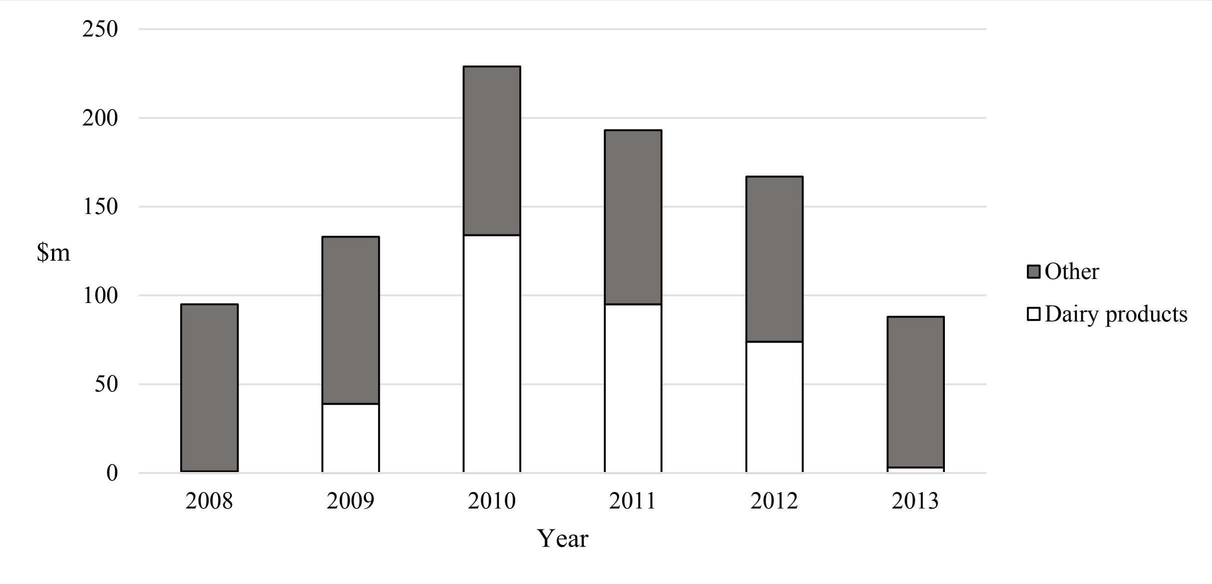
Figure 1.1: New Zealand agricultural exports to China in NZ$ million, 2008 – 2013, June years.



Source: SNZ (2010; 2013).

In contrast, New Zealand's agricultural exports to India have fluctuated over the same period, peaking in 2010 valued at $229 million. As shown in Figure 1.2, between 2008 and 2012 New Zealand's agricultural exports to India grew more than 75 per cent accounting for an increase in value of NZ$72 million. In this period, the highest growth was recorded for dairy which increased more than 19-fold (SNZ, 2010; 2013). In 2010, New Zealand dairy exports to India peaked at almost 60 per cent of all New Zealand agricultural exports to India; these were valued at $134 million. This significant increase was due to a disruption in domestic butter supply in India in 2009 (Khanna, 2009, September 3; Viju, 2009, September 11). Once India had recovered from the butter shortage, dairy imports fell. Thus, between 2012 and 2013 dairy exports declined by $71 million. In 2010, India started negotiations towards a bilateral free trade agreement with New Zealand, and in July 2013 New Zealand hosted the ninth round of the negotiations (Ministry of Foreign Affairs and Trade [MFAT], 2013). There are already numerous bilateral agreements in force between New Zealand and India covering a range of areas including wool imports and air services. Also, bilateral arrangements between the two countries exist for the areas of agriculture, plant quarantine, science and technology, information technology, education and film (MFAT, 2012). The fluctuation in New Zealand exports to India are affected by Indian trade policies which restrict imports. Therefore, an India-New Zealand FTA has the potential for India to become an important export market.

Figure 1.2: New Zealand agricultural exports to India in NZ$ million, 2008 – 2013, June years.



Notes:

(1) According to SNZ, New Zealand is not trading any type of meat products to India. This has been cross-checked with the FAO database (FAOSTAT, 2012b) which confirms that only very small amounts of pig meat have been traded between New Zealand and India between 2008 and 2013.

Source: SNZ (2010; 2013).

By-products of agricultural production include emissions of methane (CH_4) and nitrous oxide (N_2O) into the atmosphere. Greenhouse gases are linked to the climate change process as they increase the global mean surface air-temperature over time which generates a change in weather patterns and sea levels (IPCC, 2007). These emissions are predominantly generated by the ruminant animals used for production (e.g., beef and sheep) and the application of nitrogen fertiliser and manure. Agriculture is the largest contributor to New Zealand's GHG emissions with almost 50 per cent of national emissions coming from this sector (Ministry of the Environment [MfE], 2013). This is uncommon for a developed country but emphasises the significant role agriculture plays in the New Zealand economy (Wreford, 2006). However, challenges are faced if New Zealand has to commit to national and/or international agricultural GHG emissions targets.

1.1 Research objectives

New Zealand's main merchandise exports are agricultural commodities, predominantly from the meat and dairy sector. Exports to emerging countries such as India and China are growing due to the effects of changing consumption and production patterns as well as the implementation of new trade policies in these countries. This will have implications for domestic consumption, production and trade in New Zealand. The natural environment will also be affected from this development, in particular by emissions of GHG associated with agricultural production.

The main objective of this thesis is to assess how different consumption and production patterns of meat and dairy commodities and various trade policies in China and India may affect trade and GHG emissions, particularly from New Zealand.

The specific objectives are:

- To assess the impacts of different consumption and production patterns of dairy and meat commodities in India and China on net trade in New Zealand, India and China.
- To estimate the effects on producer returns in New Zealand, China and India from increased dairy and meat consumption and production in India and China.
- To determine the effects on GHG emissions (in CO_2- equivalents) from associated changes in livestock in New Zealand, India and China.
- To assess the impact of full trade liberalisation in China on dairy and meat exports from New Zealand.
- To estimate the effect of India's full trade liberalisation for New Zealand's dairy and meat exports.

1.2 Hypothesis

Based on the Lincoln Trade and Environment Model (LTEM), a partial equilibrium (PE) model that simulates impacts on international trade, production and consumption of agricultural commodities and agricultural GHG emissions, this research is able to test the following hypotheses:

- Increased meat and dairy consumption and production in China and India will increase New Zealand exports of dairy and meat commodities.
- Increased meat and dairy consumption and production in China and India will raise producer returns of dairy and meat commodities in New Zealand, China and India.
- Increased meat and dairy consumption and production in China and India will generate an increase of GHG emissions from livestock in New Zealand, China and India.
- Full trade liberalisation in China will increase the amount of meat and dairy exports from New Zealand into global markets.
- India's full trade liberalisation will raise the amount of New Zealand's meat and dairy exports into global markets.
- Full trade liberalisation in China and India will increase New Zealand's GHG emissions from livestock.

1.3 Thesis outline

This thesis is structured as follows. The following chapter provides a background to the issues involved. Global trends influencing dietary patterns in emerging countries and especially in India and China will be described, including production, consumption and trade patterns in both countries. Chapter 3 then introduces the theory of international trade, including reasons for countries to trade and impacts of trade barriers. The chapter then provides a brief introduction to the linkages between trade and the environment. Chapter 4 outlines the two main analytical modelling approaches typically applied in this type of research; the partial and general equilibrium approaches, before discussing the preferred modelling approach for this thesis. This is followed by a detailed description of this modelling approach. Chapter 5 presents data, scenarios and results, then evaluates these. The thesis finishes with a summary of the research, policy implications from the results, limitations of the study, suggestions for further research, and concluding comments.

Chapter 2
Changes in China and India's meat and dairy sector and its importance for New Zealand

2.1 Introduction

Worldwide, food consumption is growing and diets are changing. This chapter describes these changes and is structured as follows. Firstly, global trends affecting changes in diets are presented. These trends include population growth, urbanisation and income growth. Then global consumption, production and trade trends for agricultural commodities are outlined. This is followed by a brief description of the history of trade liberalisation which provides context for growth in trade. The impacts of those trends on the environment are presented by describing agricultural GHG emissions that are generated by livestock production.

Dietary changes are mainly occurring in developing countries such as China and India. Therefore, a description of China and India's consumption, production and trade of agricultural products are presented as well as agricultural GHG emissions in both countries. The trade policies of both countries are then outlined. The chapter finishes with a summary.

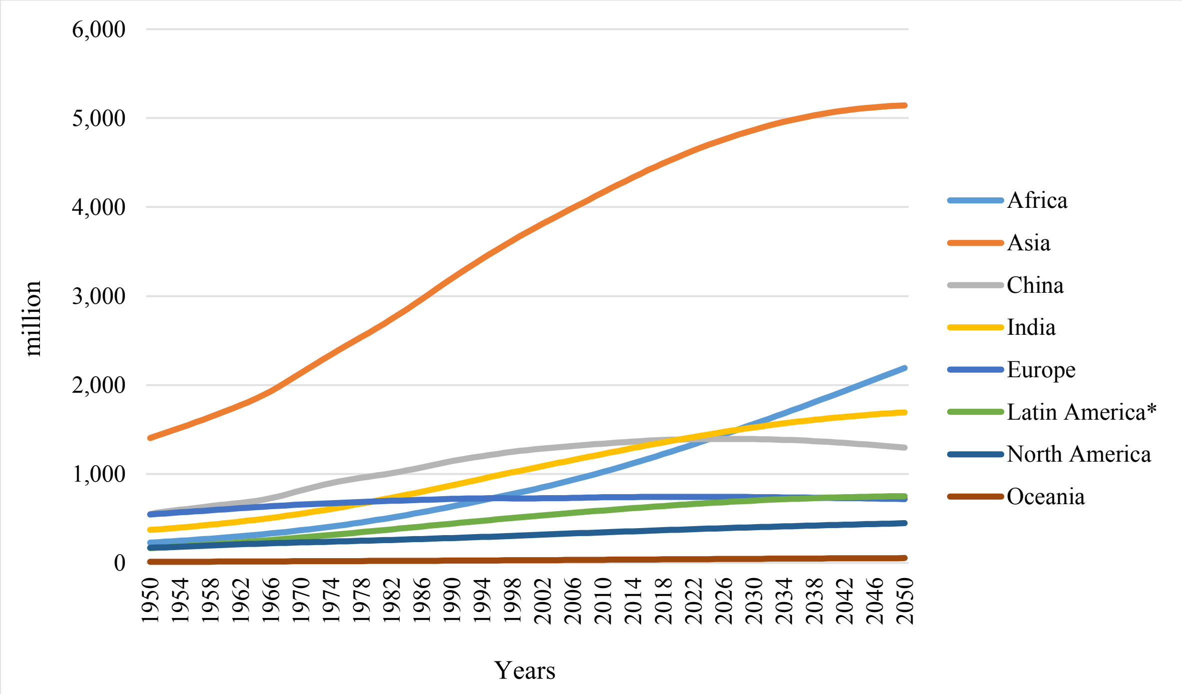
2.2 Global trends and changing dietary patterns

Global population growth, urbanisation and rising incomes have been identified as driving forces for changing dietary patterns, particularly in developing countries. These factors have a significant influence in the way global food consumption, agricultural production and international trade may develop. In this section, these trends will be outlined, including global population growth, urbanisation, global income growth as well as changes and growth in food consumption, growth in agricultural production, and the international trade of agricultural commodities. This is followed by a description of global trade history, focussing on trade liberalisation. The section finishes with a description of global GHG emissions from agricultural production.

2.2.1 Population dynamics

The world population is growing steadily (United Nations [UN], 2011). In 2012, there were 7 billion people globally (World Bank, 2012c). Since 1960, the world population has more than doubled, and projections show that the global population is expected to increase by 3.6 billion to 10.6 billion by 2050 (UN, 2012). As shown in Figure 2.1, the population growth is expected to take place in developing countries with the largest increase in Africa where population figures are projected to more than double between 2010 and 2050. This is followed by an increase in the population of Oceania and Latin America of 70 per cent and 47 per cent by 2050, respectively (UN, 2012; FAO 2012).

Figure 2.1: Population by region in millions, 1950 – 2050.



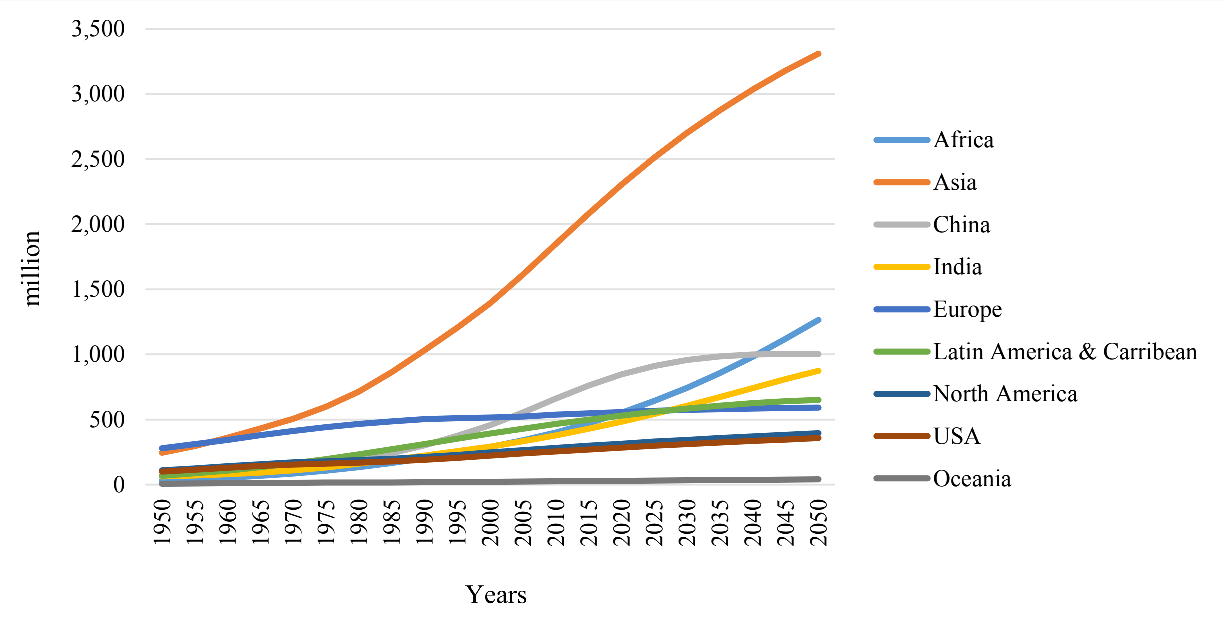
Note: Dates past 2010 are medium projections in constant-fertility variant.
Symbol: * This includes Latin America and Caribbean.

Source: UN (2011).

Most of the expected population growth will be concentrated in urban areas, especially in developing countries. The urban population is projected to grow from 3.6 billion in 2010 to 6.3 billion in 2050, this accounts for an increase of 75 per cent or 2.7 billion people. In 2010, more than 3.5 billion people were living in urban areas, compared to only 750 million people in 1960 (UN, 2012). As shown in Figure 2.2, projections show that the largest level of increase in urban population between 2010 and 2050 is projected for Africa (+216 per cent), this is followed by Asia (+79 per cent). In the same period, the total population in India is predicted to more than double while China's urban population is expected to increase more than 50 per cent (UN, 2012). Projections indicate that the global rural population will decrease by 300 million by 2050 (UN, 2012).

The proportion of total population living in urban areas is larger in the developed countries than in developing countries (an average of 73 per cent in developed countries compared with an average of 42 per cent in developing countries). However, urbanisation is increasing faster in developing countries than in developed countries. For example, urban areas in Asia are projected to increase in population by 1.4 billion by 2050. In the more developed regions, the urban population is projected to increase modestly, from 1 billion in 2011 to 1.5 billion in 2050. Thus, population growth is becoming an urban phenomenon predominantly occurring in the developing world (UN, 2012). By 2050, around seven out of ten people are expected to be urban dwellers (FAO, 2009).

Figure 2.2: Urban population by region in millions, 1950 – 2050.



Note: Dates past 2010 are medium projections in constant-fertility variant.

Source: UN (2012).

2.2.2 Global economic growth and income growth

Since the 1960s, the world economy has grown significantly with per capita incomes rising rapidly (FAO, 2009). Table 2.1 shows Gross Domestic Production (GDP) per capita in current US$ by region between 1960 and 2012. Since 1960, GDP per capita has increased significantly for all regions. In 2012, global GDP per capita was valued at US$10,281. In 2012, North America had the highest level of GDP per capita at US$51,802 while the Sub-Saharan African countries had the lowest GDP with US$1,435. In the same year, China's GDP per capita was US$6,091 which increased 7.3 per cent from the previous year while India's GDP per capita was US$1,489 which increased 2 per cent from the previous year. Between 2001 and 2010, the highest growth rate in GDP per capita was for East Asia & Pacific (+3.3 per cent), this was followed by Middle East & North Africa (+2.7 per cent). The lowest growth rate was recorded for North America where GDP per capita increased 0.7 per cent between 2001 and 2010. For the same period, China's per capita GDP increased 9.9 per cent while India's per capita GDP rose 6 per cent.

Table 2.1: Average GDP per capita in current US$ by region, 1960 – 2012.

Country	**1960 - 1970**	**1971 - 1980**	**1981 - 1990**	**1991 - 2000**	**2001- 2010**	**2011**	**2012**
East Asia & Pacific	206	728	1,781	3,609	5,106	8,501	9,037
Sub-Saharan Africa	163	422	582	546	898	1,441	1,435
Pacific island small states	*	831	1,280	1,812	2,450	3,310	3,467
North America	3,724	8,554	18,376	28,968	43,123	50,030	51,802
Middle East & North Africa	312	1,265	2,198	2,457	4,778	8,409	*
Latin America & Caribbean	478	1,304	2,111	3,798	5,707	9,686	9,575
European Union	1,359	4,642	9,413	17,745	27,944	34,826	32,782
Europe & Central	972	3,244	6,386	11,388	18,743	24,840	23,784
East Asia & Pacific	92	195	347	724	2,093	4,700	5,187
Caribbean small states	576	1,482	2,706	3,685	7,230	9,190	9,318
China	90	161	259	625	2,299	5,447	6,091
India	104	178	319	386	842	1,534	1,489
World	**592**	**1,581**	**3,079**	**5,011**	**7,381**	**10,201**	**10,281**

Symbol: * figure not available

Source: World Bank (2012a).

Various studies have projected total GDP growth rates for the world as well as for India and China; these are summarised in Table 2.2. These studies indicate that China and India's GDP will grow at a larger rate than global GDP. For China, projected growth rates range from 5.6 per cent per annum (Nin, Hertel, Foster & Rae, 2004) to 8 per cent per annum (Anderson & Strutt, 2012a). Projections for India's GDP growth range from 5.5 per cent per annum (Rosegrant, Paisner, Meijer & Witcover, 2001) to 7.9 per cent per annum (Anderson & Strutt, 2012a). Projections from World Bank (2012b) indicate that China's GDP is expected to grow annually by 7.6 per cent by 2016 while India's GPD is projected to grow annually by an average of 5.5 per cent by 2016.

Table 2.2: Total GDP growth per year for India, China and the world from selected studies, in per cent.

Study	Period	India	China	World
Nin et al. (2004)	1995 - 2010		5.6	
Rosegrant et al. (2001)	1997 - 2020	5.8	6	2.9
FAO (2006)	1997/99 - 2015	5.5(1)	5.4(2)	3.5
	2015 - 2030	5.4(1)	6.3(2)	3.8
Anderson & Strutt (2012)	2004 - 2030	7.9	8.05	2.5
Anderson & Strutt (2011)	2004 - 2030	6.2(1)	6.6	
World Bank (2012b)	2012-2016	5.5	7.6	1.4

Notes:
(1) This growth rate is for South Asia region.
(2) This growth rate is for East Asia region.

2.2.3 Increasing food consumption and changing dietary patterns towards more livestock products

The growing world population, urbanisation and rising incomes have led to increases of food consumption (OECD FAO, 2012). In developing countries, the growth in food consumption is accompanied by structural change in dietary patterns away from staples such as roots and tubers towards more livestock products and vegetable oils (OECD FAO, 2011; FAO, 2012). Urbanisation and income growth are generally considered to be the strongest drivers of increased consumption of livestock products in these countries (Regmi, 2001; OECD FAO, 2011; Goel, 2010; Vepa, 2004; FAO, 2009). Several studies have found that urban residents typically consume more high value products such as meat and larger amounts of pre-cooked, fast and convenience foods than people in rural areas (Schmidhuber & Shetty, 2005; Vepa, 2004; King, Tietyen & Vickner, 2000; Rae, 1998). This is due to relatively higher income elasticities of demand[1] for meat and dairy products in cities compared to rural areas (Pingali & Khwaja, 2004).

Table 2.3 shows global food consumption by category between 1961 and 2009. It can be seen that since the 1960s global food consumption for all categories has increased steadily. In 2009, globally 977 million tonnes of cereals, 581 million tonnes of milk and 279 million tonnes of meat were consumed. Between 1960 and 2009 global consumption of meat almost quadrupled and global milk consumption has more than doubled. A smaller increase was recorded for the

[1] The income elasticity of demand measures how the quantity demanded changes as consumer income changes. For normal goods, higher income raises the quantity demanded, thus normal goods have positive income elasticities. Luxury goods have high positive income elasticities larger than 1 (Mankiw, 2007).

consumption of pulses and roots increasing by 80 per cent over the same period. Growth in livestock product consumption has been occurring mainly in Asian countries. In Asia, meat consumption increased 20-fold and milk consumption increased more than 5-fold between 1961 and 2009. Changes in food consumption by category in world regions (including India and China) between 1961 and 2009 are given in Appendix A.

Table 2.3: Global food consumption by category in million tonnes, 1961 – 2009.

Category	1961	1971	1981	1991	2001	2009
Cereals	391	504	644	793	897	977
Fruits	115	163	204	263	368	485
Oilcrops	15	20	24	30	41	48
Pulses and roots	265	303	309	336	417	451
Vegetable oils	14	22	35	50	62	77
Animal fats	12	15	17	19	20	22
Eggs	14	19	25	35	50	59
Meat	70	102	136	180	232	279
Milk	230	280	342	403	478	581

Source: FAOSTAT (2012a).

Meat and dairy consumption is predicted to continue growing. Projections by the OECD FAO Agricultural Outlook 2012 -2021 show that global food consumption in all product categories will increase further with higher growth rates occurring in developing countries. World meat consumption will increase steadily and is expected to expand by 19 per cent by 2021, this is a slightly lower rate than between 2000 and 2010 (+22 per cent). Poultry meat consumption is expected to grow the fastest (+37 per cent), reaching parity with pig meat consumption by 2021. Beef and sheep meat consumption is expected to grow by 12 per cent and 11 per cent by 2021, respectively (OECD FAO, 2012). As mentioned above, most of the increase is projected to occur in developing countries (mostly from economies in Asia, Latin America and oil exporting countries) where meat intake is expected to grow by 28 per cent, compared with up to 10 per cent in the developed and OECD countries (OECD FAO, 2012).

Similarly, global consumption of dairy products, both per capita and overall, will continue to grow (OECD FAO, 2012). The most rapid growth is projected to occur in developing countries where the consumption of dairy products is expected to increase by 30 per cent by 2021 compared to 11 per cent in developed countries. The highest increase is projected for SMP consumption (+41 per cent), this is followed by cheese (+28 per cent) and butter consumption (+33 per cent) (OECD FAO, 2012).

Global wheat consumption is expected to reach nearly 755 million tonnes by 2021 of which 67 per cent is for human consumption, 20 per cent for feed and 13 per cent is used for other activities such as biofuels. Per capita wheat consumption is predicted to remain steady at around 65 kg per person; however the use of coarse grains is predicted to grow by 18 per cent to 239 million tonnes by 2021. Other food products of which consumption is expected to grow significantly by 2021 are vegetable oils (+32 per cent) and sugar (+33 per cent) (OECD FAO, 2012). In Asia, wheat and rice consumption is projected to increase by 14 and 12 per cent by 2021, respectively. These projected growth rates are smaller than the predicted growth in livestock consumption in Asia (OECD FAO, 2012).

Growing demand is likely to increase livestock populations. OECD FAO (2012) projections show that the global population of cattle will increase to 1.8 billion by 2021. As a consequence, demand for feed grains and protein meals is expected to grow. Projections show that the demand for coarse grains for animal feed will increase to 722 million tonnes by 2021 which is an increase of 20 per cent from 2011 (OECD FAO, 2012).

2.2.4 Production and trade of agricultural products

Similarly to changes in food consumption, agricultural production and international trade of agricultural commodities are changing. Table 2.4 shows global food production by category between 1961 and 2009. Globally, 2,252 million tonnes of cereals, 698 million tonnes of milk and 285 million tonnes of meat were produced in 2009. Between 1961 and 2009, the production of meat and milk increased significantly. Over this period, meat production more than quadrupled and milk production more than doubled. Other food products with significant growth levels between 1961 and 2009 were vegetable oils (increasing almost 8-fold) and eggs (almost quadrupled). The smallest growth levels were recorded for pulses and roots. Changes in food production by category and region between 1961 and 2009 are given in Appendix B.

The increase in food production is dominated by a few countries. Between 1961 and 2009, the highest increase in milk and meat production was recorded in Asia. Since the early 1990s, meat and milk production more than doubled in the region with China and India accounting for the largest growth rates between 1991 and 2009 (FAOSTAT, 2012a).

Table 2.4: Global food production by category in million tonnes, 1961 – 2009.

Category	1961	1971	1981	1991	2001	2009
Cereals	799	1,188	1,489	1,710	1,904	2,252
Fruits	170	236	290	346	471	593
Oilcrops	105	148	211	278	383	490
Pulses and roots	486	559	567	612	724	784
Vegetable oils	19	29	44	65	99	144
Animal fats	18	23	28	31	32	36
Eggs	15	21	28	39	56	68
Meat	71	104	138	183	235	285
Milk	342	392	466	530	585	698

Source: FAOSTAT (2012a).

Projections from the OECD FAO Agricultural Outlook 2012 – 2021 predict that global food production will increase further but at a slower rate. Agricultural production will grow by 1.7 per cent per annum for the period 2012 to 2021 compared to an annual growth rate of 2.6 per cent between 2001 and 2011. The growth in global meat production will slow down from an annual average 2.2 per cent in 2001 to 2011 to 1.8 per cent between 2012 and 2021. This is largely due to slower growth in Latin America (OECD FAO, 2012). Global milk production is projected to grow by 154 million tonnes accounting for an increase of 18 per cent between 2012 and 2021. The majority of this (70 per cent) is predicted to come from developing countries. India and China alone account for nearly 40 per cent of the projected global growth. Milk production will increasingly originate from cows as opposed to other sources such as camel, buffalo, sheep and goat milk which are important sources of milk production in many countries (OCED FAO, 2011).

Productivity growth is an essential driver of agricultural production and affects food supply, international trade and global commodity markets. Measured over time, productivity can be seen as a measure for changing efficiency or industry competitiveness and technological change (OECD FAO, 2012). Table 2.5 shows productivity growth rates in agriculture in world regions between 1961 and 2009 estimated by the OECD FAO (2012). Between 1961 and 2009 productivity growth overall was higher in developed countries (on average +2 per cent p.a.) than in developing countries (on average +1.5 per cent p.a.). However, between 2001 and 2009 productivity in China's agricultural sector rose by 3 per cent which was higher than the annual growth rate of all developing countries (+2.2 per cent p.a.) and developed countries (+2.5 per cent p.a.). The productivity growth rate in South Asia (including India) was 2 per cent between 2001 and 2009 which was below the growth level of all developing countries.

Table 2.5: Productivity growth rates in agriculture in world regions, 1961 – 2009, in per cent.

Country/region	1961-1970	1971-1980	1981-1990	1991-2000	2001-2009
Brazil	0.19	0.53	3.02	2.62	4.03
China	0.93	0.6	1.69	4.16	2.83
South Asia (including India)	0.63	0.86	1.31	1.22	1.96
Oceania	-0.14	0.47	-0.73	0.54	1.33
All developed countries	0.99	1.64	1.36	2.23	2.44
All developing countries	0.69	0.93	1.12	2.22	2.21

Source: OECD FAO (2012).

In their study Ludena, Hertel, Preckel, Foster and Nin (2007) projected productivity growth rates for different agricultural sectors for different regions between 2001 and 2040. As shown in Table 2.6, the increase of productivity in ruminants is predicted to be particularly strong in some emerging economies such as China with the largest growth rates predicted for China where production is expected to grow by 3 per cent per annum while productivity in ruminants in South Asia (including India) is projected to grow by 1.5 per cent. This is greater than global productivity growth in ruminants which is predicted to grow by 1 per cent in the projection period. However, agricultural productivity growth is still projected to be low in developing countries, in particular in Sub-Saharan Africa (Ludena et al., 2007).

Table 2.6: Average projected annual productivity growth rates[1,2] by region and sector, 2001 – 2040, in per cent.

Country/region	Average annual growth	Productivity growth ruminants	Productivity growth non-ruminants	Productivity growth crops
China	3.11	3.01	6.6	1.45
South Asia (including India)	1.16	1.48	3.48	0.96
East and South East Asia	-0.08	-1.24	3.67	-0.66
Middle East and North Africa	0.22	-0.31	-0.28	0.45
Sub-Saharan Africa	0.78	0.57	-0.05	0.91
Latin America and Caribbean	1.14	1.50	4.55	0.62
Economies in Transition	1.24	0.53	2.09	1.39
Industrialised countries	0.77	0.27	0.63	1.14
World	**1.38**	**0.82**	**3.6**	**0.94**

Notes:

(1) Weighted average productivity growth rates are estimated using output share of each agricultural sector in 2001.

(2) Total factor productivity growth rates are presented (see Section 2.3.2).

Source: adapted by Ludena et al. (2007).

Agricultural trade

Agricultural trade has been increasing since 1960. Table 2.7 shows the global trade flows of agricultural commodities between 1961 and 2010. In this period, the highest growth levels for agricultural exports and imports were recorded for milk, vegetable oils and meat.

Table 2.7: Global trade flows by agricultural commodity in US$ million, 1961 – 2010.

Trade flow	Commodity	1961	1971	1981	1991	2001	2010
Imports	Animal fats	185	402	1,387	1,004	1,065	2,834
	Cereals	5,584	9,245	49,408	36,844	39,509	95,381
	Veg. oils(1)	953	2,024	8,302	12,058	16,557	65,243
	Fruit/Veg.(2)	3,919	8,244	31,989	63,473	76,398	184,339
	Oilseeds	1,395	2,746	11,660	11,219	17,223	60,974
	Pulses	160	338	1,919	2,648	3,284	7,640
	Meat(3)	1,850	4,654	17,906	33,967	39,601	94,993
	Milk(4)	213	749	4,459	7,412	9,684	21,124
	Agricultural products	**34,779**	**60,783**	**253,835**	**353,098**	**441,842**	**1,103,506**
	Merchandise trade	**138,887**	**356,692**	**2,023,366**	**3,618,953**	**6,282,720**	**15,356,049**
Exports	Animal fats	217	374	1,252	939	950	2,936
	Cereals	4,992	8,202	44,170	33,514	35,969	86,341
	Veg. oils(1)	859	1,953	7,658	10,997	14,644	64,763
	Fruit/Veg.(2)	3,378	7,022	27,653	54,288	69,381	178,219
	Oilseeds	1,245	2,404	10,482	10,182	15,236	55,485
	Pulses	152	321	1,744	2,469	2,942	7,237
	Meat(3)	1,713	4,667	18,223	32,941	40,117	97,550
	Milk(4)	241	799	3,874	6,987	9,741	21,212
	Agricultural products	**32,114**	**55,926**	**233,147**	**328,659**	**414,356**	**1,077,882**
	Merchandise trade	**135,310**	**351,278**	**1,990,446**	**3,499,256**	**6,123,742**	**15,226,272**

Notes:
(1) This inlcudes vegetable oils.
(2) This includes fruit and vegetables.
(3) Meat includes bovine meat, pig meat and poultry meat
(4) Milk includes dry milk and fresh milk.

Source: FAOSTAT (2012b).

Major trading countries and their share of world trade for selected agricultural commodities in 2010 are presented in Table 2.8. It can be seen that Brazil was the world's largest beef/veal exporter with 25 per cent share of the world trade in 2010. New Zealand was the largest sheep meat exporter with 39 per cent of world trade. In 2010, New Zealand was the leading exporter for whole milk powder (WMP) and butter with 41 and 26 per cent share of world trade, respectively.

In 2010, countries with high net dairy imports were China (accounting for 17 per cent of the world imports of WMP), Mexico (accounting for 7 per cent of the world imports of skim milk powder (SMP)), Germany (accounting for 12 per cent of the world's cheese imports) and France (accounting for 11 per cent of the world's butter imports). With regards to meat imports, the US accounted for 11 per cent of the world's imports of beef and veal while France took 13 per cent of the world's sheep meat imports.

Projections from the OECD FAO Agricultural Outlook 2012 – 2021 show that traditional exporters of the majority of agricultural products, such as the European Union (EU), New Zealand, the United States (US) will remain important in global trade. However, countries with developing agricultural sectors including Brazil and China, are expected to have increased global market shares. World meat trade (namely beef, pig meat, poultry meat and sheep meat shipments) is expected to grow by 1.5 per cent annually by 2021. Developing countries are also expected to increase their share of international meat trade over the projection period (OECD FAO, 2012).

World trade in dairy products is predicted to remain dominated by developed countries including New Zealand, Australia, the EU and the US and will continue to grow (OECD FAO, 2012). However, EU exports, historically the key dairy exporter, are expected to decline by 2021. Countries in Asia, especially China, and oil-rich countries in North Africa and the Middle East will import more (OECD FAO, 2011). Among the dairy commodities, the highest growth is predicted for exports of dairy powders with exports of SMP projected to increase by 34 per cent while WMP exports are projected to increase by 30 per cent by 2021. New Zealand is projected to remain the main WMP exporter with volumes growing more than 50 per cent from 2011 to 2021. By 2021, New Zealand is estimated to account for more than half of the global WMP trade (OECD FAO, 2012). Global export trade volumes for wheat and coarse grains are projected to increase by only 17 per cent and 20 per cent, respectively by 2021. The developed countries continue to dominate international wheat and coarse grains trade in absolute volume terms, and account for most of the predicted increase in coarse grain shipments by 2021 (OECD FAO, 2012).

Table 2.8: Major trading countries by agricultural commodity and the respective share of world trade, 2010.

Trade Flow	Commodity	2010		2000-2010	
		Country	Share of world trade (%)	Country	Share of world trade (%)
Import	Animal fats	Mexico	14.45	Mexico	13.24
	Cereals	Japan	7.63	Japan	8.83
	Vegetable oils	China	14.41	China	13.21
	Fruit and vegetables	US	12.01	US	12.19
	Oilseeds	China	47.55	China	34.47
	Pulses	India	20.43	India	22.45
	Rice	Philippines	7.62	Philippines	5.31
	Beef and veal	US	10.91	US	15.75
	Pig meat	Italy	9.39	Japan	11.28
	Poultry meat	Hong Kong	8.45	Russia	10.81
	Sheep meat	France	12.88	France	14.53
	Butter	France	10.47	France	10.08
	Cheese	Germany	11.96	Germany	12.71
	SMP	Mexico	7.48	Netherlands	8.66
	WMP	China	17.03	Algeria	8.27
Export	Animal fats	US	35.18	US	35.76
	Cereals	US	25.59	US	29.07
	Vegetable oils	Indonesia	27.8	Malaysia	26.16
	Fruit and vegetables	China	8.05	China	7.35
	Oilseeds	US	36.49	US	36.93
	Pulses	Canada	36.01	Canada	29.59
	Rice	Thailand	27.28	Thailand	28.55
	Beef and veal	Brazil	14.33	Brazil	15.04
	Pig meat	Germany	15.47	Denmark	13.52
	Poultry meat	Brazil	25.38	US	27.89
	Sheep meat	New Zealand	38.75	New Zealand	38.93
	Butter	New Zealand	25.94	New Zealand	24.67
	Cheese	Germany	18.54	Germany	17.50
	SMP	US	18.83	New Zealand	15.93
	WMP	New Zealand	40.95	New Zealand	30.43

Source: FAOSTAT (2012b).

The increase in global trade flows is based on a long history of trade reforms with countries and regions successively reducing trade barriers. The next section will describe the history of global trade policies.

2.2.5 Trade liberalisation: GATT, the Uruguay Round and the WTO

In 1944, a set of post-war economic institutions were established, one of which was the General Agreement on Tariffs and Trade (GATT) which was founded to reduce trade barriers and promote free trade. In a series of negotiations among many of the world's countries it has achieved the reduction of the average tariff among member countries from about 40 per cent in the 1940s to about 5 per cent in 2007 (Mankiw, 2007; Salvatore, 2005).

One of the most ambitious rounds of GATT multilateral trade negotiations was the Uruguay Round (1986 – 1994) with 123 countries participating (Salvatore, 2005). The Uruguay Round covered a wide range of trade issues and reducing trade barriers for agricultural commodities was a central issue. This was the first time that agricultural trade was in the focus of trade negotiations as it was effectively excluded from previous rounds (Hawkes & Murphy, 2010; Reinert, 2012).

The Uruguay Round opened the way for further reductions in tariffs during subsequent rounds of negotiations. Furthermore, it attempted to include not just tariffs but also to reverse the trend of rising non-tariff trade barriers which had increasingly affected agricultural sectors in developed countries. The growth in non-tariff barriers had progressively affected New Zealand's trade, including the existence of quotas for exports into markets of developed countries (MAF & MFAT, 2003).

When the Uruguay Round Agreement of Agriculture (AoA) came into effect in 1995, food became part of trade agreements (Hawkes & Murphy, 2010; Salvatore, 2005). The AoA set the standard of how agriculture is to be implemented in regional and bilateral trade agreements. The goals of the AoA were to improve market access for agricultural commodities, to reduce domestic support for the agricultural sector in terms of price-distorting subsidies and quotas, to remove export subsidies on agricultural products successively and to harmonise sanitary and phytosanitary measures between member countries (Hawkes & Murphy, 2010).

Another major reform initiated by the Uruguay Round was the creation of the World Trade Organization (WTO) to replace GATT. The new organisation came into force in 1995 after subsequent ratification by the US and other member countries on establishing new global trading rules (Mankiw, 2007). The WTO has several functions. It provides a forum for governments to negotiate and formalise trade agreements, it administers trade agreements and attempts to resolve trade disputes aimed at enforcing participants' adherence to WTO agreements which are signed by representatives of member governments (World Trade

Organization [WTO], 2012a). Most of the issues that the WTO focuses on derive from previous trade negotiations, especially from the Uruguay Round.

Since its creation, the number of regional arrangements reported to the WTO rose frequently. As of 31 January 2014, 583 regional and bilateral trade agreements had been notified to GATT/WTO of which 377 were in force (WTO, 2013) accounting for more than 97 per cent of global trade. Increasingly, South-South and South-North regional agreements have emerged such as the Central American Free Trade Agreement (CAFTA) between Central America and the US (Braun, 2007).

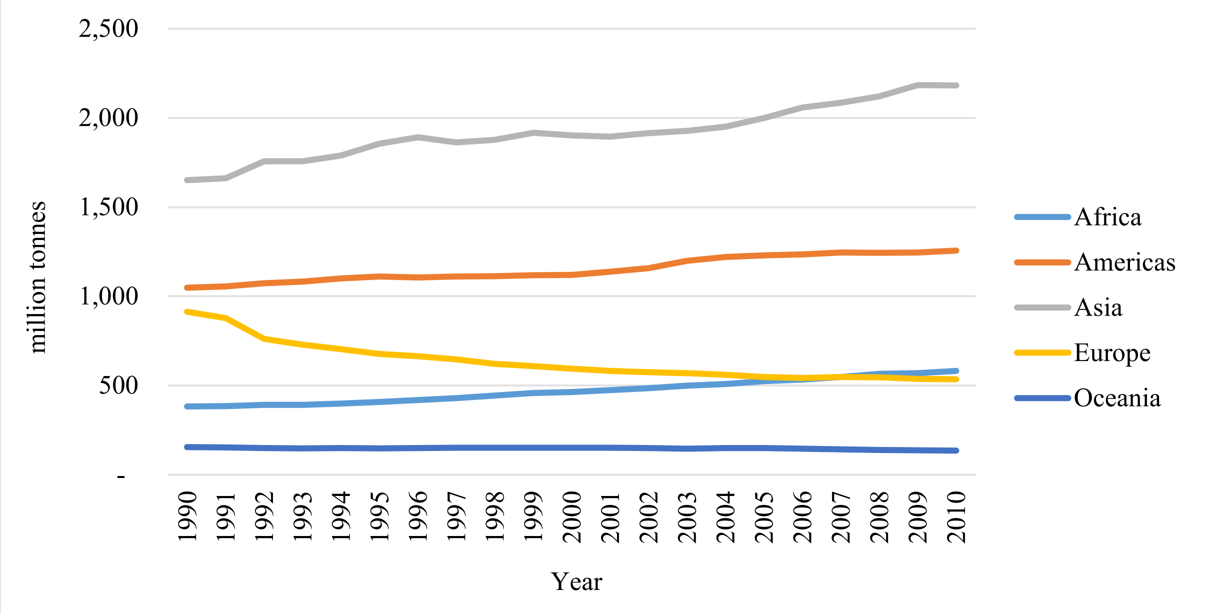
The current trade-negotiation round of WTO with multilateral trade talks began in Doha/Qatar in 2001 including more than 150 countries aiming to reduce global trade barriers. As of 2008, talks have stalled over a divide on major issues but largely because of the disagreements around agriculture (Hawkes & Murphy, 2010).

2.2.6 Global agricultural GHG emissions and the contribution of livestock production and consumption to climate change and GHG emissions

Agriculture releases significant amounts of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) into the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) (2007) found that agriculture accounts for 10-12 per cent of total global anthropogenic emissions of GHG. Agriculture contributes about 47 per cent of total anthropogenic CH_4 emissions and 58 per cent of total anthropogenic N_2O emissions. However, there is a wide range of uncertainty in the estimates of both the agricultural contribution and the anthropogenic total (IPCC, 2007). The United States Environmental Protection Agency (US-EPA) (2006) estimated that N_2O emissions from soils (e.g., through the use of nitrogen fertiliser) and CH_4 from enteric fermentation (e.g., though ruminants digestion process) are the largest sources. In 2005, this accounted for 38 per cent and 32 per cent of total non-CO_2 emissions from agriculture, respectively (US-EPA, 2006).

In 2010, globally 4,689 million tonnes of GHG emissions (CO_2- equivalents) were emitted by the agricultural sector, this was 13 per cent more than in 1990 (FAOSTAT, 2013). As shown in Figure 2.3, regional agricultural GHG emissions were the highest for Asia in 2010. Between 1990 and 2010, the highest growth of agricultural GHG emissions were recorded for Africa (+52 per cent), then Asia (+32 per cent). In contrast, in the same period GHG emissions from agriculture in Europe fell by 41 per cent (FAOSTAT, 2013).

Figure 2.3: Agricultural GHG emissions (in CO_2-equivalents) by region in million tonnes, 1990 – 2010.



Source: FAOSTAT (2013).

Ruminant animals are the predominant source of GHG from agriculture. GHG emissions from livestock are caused in all main stages of the production cycle (FAO, 2009). For example, emissions from feed production and pastures are related to the production and application of chemical fertilisers and pesticides, to soil organic-matter losses and to transportation. Deforestation due to pasture and feed-crop cultivation emits large amounts of carbon into the atmosphere. At farm level, CH_4 and N_2O emissions are generated by enteric fermentation and manure management. Methane is exhaled by ruminant species (i.e., cattle, buffalo, goat and sheep) as a by-product of the process of microbial/anaerobic fermentation in the animal's rumen (FAO, 2009; Steinfeld et al., 2006). Nitrous oxide is emitted from manure during storage and spreading, and CH_4 is also released when manure is stored in anaerobic and warm conditions. Nitrous oxide and CH_4 emissions from animal manure alone contribute to more than 5 per cent of global GHG emissions. Finally, animal slaughter as well as the processing and transportation of livestock products generate GHG emissions that are predominantly associated with the use of fossil fuel and infrastructure development (FAO, 2009).

The negative impacts of livestock production on the environment are expected to grow, particularly with an increased demand for livestock products (Steinfeld et al., 2006; IPCC, 2007). The global growth in beef production will result in an increase of GHG emissions (IPCC, 2007). In particular, GHG emissions from livestock from East Asia are predicted to increase by 2020 due to increases in meat and milk production in these countries. In South Asia, GHG emissions are expected to rise predominantly because of the increasing use of manure and nitrogen fertilisers to meet the demand for food. Western Europe is the only region where GHG emissions from agriculture are projected to fall by 2020 (IPCC, 2007).

Table 2.9 shows global GHG emissions from different livestock types from enteric fermentation. In 2010, the highest GHG emissions from enteric fermentation from livestock were generated by beef cattle (54 per cent), followed by dairy (19 per cent), then sheep (6 per cent) (FAOSTAT, 2013). As mentioned above, most emissions from livestock are generated in the production phase which requires most resources including chemical fertiliser, feed, fuel, pesticides and water (Hamerschlag, 2011).

Table 2.9: Global GHG emissions (in CO_2-equivalents) from enteric fermentation by livestock type in million tonnes, 2010.

Type	GHG emissions	Percentage share
Dairy cattle	390.49	19%
Non-dairy cattle	1,091.50	54%
Pigs	23.20	1%
Sheep	128.87	6%
Other	384.83	19%
Total Animals	**2,018.90**	**100%**

Source: FAOSTAT (2013).

In New Zealand, livestock numbers and the use of nitrogen are the predominant causes of GHG emissions from agriculture (Cagatay, Saunders & Wreford, 2003). In 2011, almost 50 per cent of GHG emissions were generated from agricultural production (MfE, 2013). This large share is uncommon for a developed country but emphasises the importance of the agricultural sector to the New Zealand economy. The largest share of agricultural GHG emissions in New Zealand comes from ruminant animals, of which enteric fermentation accounts for 55 per cent. In 2010, GHG emissions from enteric fermentation from dairy cattle accounted for 42 per cent of all GHG emissions from livestock, this was followed by beef accounting for 31 per cent, then sheep accounting for 26 per cent (FAOSTAT, 2013).

In summary, this section showed that rapid income growth and urbanisation since the 1960s, combined with underlying population growth, are driving forces in dietary changes in many developing countries, particularly in Asia. These developments are leading to increases in meat and dairy consumption and production in many developing countries. Livestock production has been identified as a large contributor to climate change which affects the amount of agricultural GHG emissions globally. China and India are often mentioned in the context of changing dietary patterns where changes in food composition towards meat and dairy products are most visible and most significant. The following sections will provide more insights into the dietary convergences occurring in these two countries.

2.3 Changes in China

The People's Republic of China had a population of 1.35 billion in 2012 (World Bank, 2012c) which is expected to slightly grow by a total of 3 per cent by 2030 (UN, 2012). In 2012, the total GDP of China was US$8.3 trillion with a real growth rate of 8 per cent from the previous year (Wold Bank, 2012a). In the same year, agriculture accounted for around 10 per cent of GDP (New Zealand Trade and Environment [NZTE], 2011a; World Bank, 2012a). Total GDP is projected to grow by 8 per cent annually to 2016 (World Bank, 2012a). In 2012, China's per capita GDP was valued at US$6,091 p.a. with a growth rate of 7.8 per cent from the previous year. Since 2010, China is the world's second-largest economy in terms of GDP behind the US (NZTE, 2011a; World Bank, 2012a).

China's dietary patterns are changing and particularly the consumption of meat and dairy products is increasing (see Dong & Fuller, 2007; OECD FAO 2012). Hence, China has contributed to the global increase of livestock product consumption, production and trade. In this section, China's food consumption, production and trade figures for selected agricultural commodities will be given. This is followed by a description of China's trade policies. The section finishes with an outline of China's agricultural GHG emissions, particularly from livestock.

2.3.1 Food consumption in China

A traditional Chinese diet had a low intake of animal products and a large proportion of cereals (rice or wheat) (Mendez, Shufa & Popkin, 2004). The FAO (2006) estimated that in China in the 1960s meat contributed only 4 per cent to the average daily per capita calorie supply while cereals (rice or wheat) provided almost 67 per cent to the average daily diet with starchy roots (e.g., potatoes) covering almost 14 per cent of the diet. Table 2.10 shows that China's dietary patterns have changed. The table shows food consumption[2] by category in China between 1960 and 2009. This data was derived from FAOSTAT; this source was selected as it had consistent and comparable longitudinal data for both, China and India. It can be seen that since the early 1960s the consumption of animal products has increased significantly. Significant growth levels were recorded for meat which increased 40-fold, this is followed by milk consumption which

[2] This is food availability for human consumption (FAOSTAT, 2012a).

increased 30-fold, and eggs which increased 20-fold between 1960 and 2009. In contrast, consumption of pulses and roots increased by only 10 per cent during the same period.

Table 2.10: Food consumption in China by category in million tonnes, 1961 – 2009.

Category	1961	1971	1981	1991	2001	2009
Cereals	61.58	111.19	160.31	196.01	209.42	206.68
Fruits	2.88	4.23	8.36	21.84	59.57	98.72
Oilcrops	3.39	5.36	5.69	5.95	9.43	9.17
Pulses and roots	82.65	97.83	88.85	79.55	101.29	90.81
Vegetable oils	0.83	1.63	3.49	7.20	8.69	12.16
Animal fats	0.17	0.54	0.84	1.53	2.79	2.96
Eggs	1.39	1.80	2.73	8.64	20.44	25.20
Meat	2.56	8.58	15.35	32.87	63.61	79.46
Milk	1.66	1.92	3.19	7.57	14.28	40.71

Source: FAOSTAT (2012a).

The increase in meat and dairy consumption in China is expected to continue as shown in Table 2.11. Projections from the OECD FAO Agricultural Outlook 2012 – 2021 show that milk consumption is projected to increase by 10 million tonnes by 2021, this is an increase of 26 per cent. Similarly, beef and veal consumption is projected to increase almost 20 per cent by 2021 while sheep meat consumption is projected to increase by only 6 per cent. In contrast, wheat consumption is projected to decrease by 10 million tonnes which is a drop of 11 per cent by 2021.

Table 2.11: Projections of meat and dairy consumption in China in million tonnes, 2012 and 2021.

Commodity	2012	2021	Percentage change 2012 - 2021
Beef and veal	5.46	6.47	19%
Pig	52.25	60.14	15%
Poultry	18.44	24.23	31%
Sheep meat	4.09	4.34	6%
Milk	38.07	48.13	26%
Butter	0.16	0.18	17%
Cheese	0.35	0.43	23%
SMP	0.19	0.23	20%
WMP	1.43	1.70	19%

Source: OECD FAO, (2012).

A factor that affects food consumption is the income elasticity of demand which measures how the quantity demanded changes as income changes (Mankiw, 2007). Table 2.12 presents various estimates of income elasticities for China. The majority of these suggest that meat and dairy products in China are normal goods[3]. In contrast, Ma & Rae (2004) indicated that dairy products are luxury goods[4]. Rosegrant et al. (2001) projected income elasticities for meat and dairy products for East Asia (including China) in 2020. In their study, they predicted that meat and beef products will be normal goods by 2020.

Table 2.12: Income elasticities of demand for meat and milk products in China.

Source	**Milk**	**Dairy products**	**Milk powder**	**Beef**	**Mutton/ sheep meat**	**Pork**	**Poultry**
Tongeren & Huang (2004)	0.80						
Ma & Rae (2004)		1.77		0.74	0.45	0.68	1.49
Rosegrant et al. (2001)[1]	0.63			0.82	0.54	0.61	0.91
Rosegrant et al. (2001)[1,2]	0.46			0.63	0.37	0.52	0.82
Wang, Zhou & Yang (2004)			0.50	0.50			

Notes:
(1) Elasticities are for East Asia region, including China.
(2) Projections by 2020.

2.3.2 Food production in China

China is the largest food producer of the world (FAOSTAT, 2012a). Table 2.13 shows food production in China by category between 1961 and 2009. In 2009, China produced 208 million tonnes of cereals, 78 million tonnes of meat and 40 million tonnes of milk. Between 1961 and 2009, China’s food production more than quadrupled with high shares coming from meat production (accounting for an increase of more than 40-fold) and milk production (accounting for an increase of more than 30-fold). In contrast, the production of pulses and roots increased by only 60 per cent over the same period.

[3] Income elasticities of demand for normal goods are positive and between 0 and 1 (Mankiw, 2007).
[4] Income elasticities of demand for luxury goods are positive and larger than 1 (Mankiw, 2007).

Table 2.13: Food production by category in China in million tonnes, 1961 – 2009.

Category	1961	1971	1981	1991	2001	2009
Cereals	90.94	172.81	237.51	336.63	338.69	417.79
Fruits	3.26	5.21	9.46	24.09	68.95	115.88
Oilcrops	10.57	17.73	26.08	37.67	52.81	57.82
Pulses and roots	100.61	138.62	142.13	143.39	188.89	160.60
Vegetable oils	1.10	2.00	3.94	6.31	12.47	18.83
Animal fats	0.17	0.61	0.90	1.85	3.09	3.73
Eggs	1.52	2.00	3.03	9.46	22.50	27.77
Meat	2.55	8.71	15.44	33.38	62.99	78.09
Milk	1.85	2.03	3.18	7.62	14.52	40.39

Source: FAOSTAT (2012a).

Projection trends for the production of meat and dairy commodities in China are provided by the OECD FAO Agricultural Outlook 2012 – 2021. Table 2.14 shows that the highest growth rate is expected for poultry production which is projected to increase by 30 per cent by 2021. Beef and veal production is predicted to increase almost 20 per cent by 2021. Among dairy commodities, the highest increases are predicted for milk production which is projected to increase by 12 million tonnes to accounting for an increase of 26 per cent by 2021.

Table 2.14: Projections of meat and dairy production in China in million tonnes, 2012 and 2021.

Commodity	2012	2021	Percentage change 2012 - 2021
Beef and veal	5.46	6.44	18%
Pig meat	52.35	60.10	15%
Poultry meat	18.34	23.80	30%
Sheep meat	4.04	4.28	6%
Milk	48.13	60.43	26%
Butter	0.12	0.14	15%
Cheese	0.32	0.37	17%
SMP	0.06	0.06	10%
WMP	1.09	1.36	24%

Source: OECD FAO (2012).

As mentioned above, productivity growth is a driving force for agricultural production that impacts food supply, international trade and global commodity markets. There are two methods of measuring productivity growth, this is partial and total factor productivity growth. Partial factor productivity (PFP) measures only some inputs into agriculture such as '*output per head of livestock*' and ignores factor substitution. Total factor productivity (TFP) is a measure of output per unit input. It is argued to be a more accurate measure of productivity growth as it accounts for all relevant inputs. For example, if increased output per head of livestock is gained by increased intensive feeding of animals, then TFP growth may remain unchanged, despite the growth in PFP of output per head because another input might have changed. However, TFP measurement requires information about all inputs to specific agricultural subsectors which is not always available, thus often PFP is calculated (Ludena et al., 2007). Several studies have estimated partial and total factor productivity growth rates for China's livestock sector. Table 2.15 illustrates historical and future partial and total factor productivity growth rates for the dairy and meat sector in China from selected studies. According to the OECD FAO (2012), partial factor productivity growth in the beef sector was 8.5 per cent annually between 1985 and 2011. This is higher than growth rate projections for the beef sector for the period 2012 to 2021 which suggest an annual growth of 5 per cent. Similarly, Rae & Hertel (2000) projected an annual partial factor productivity growth rate of the beef sector of 4.2 per cent between 1995 and 2005. Rae, Ma, Huang & Rozelle (2006) estimated an annual total factor productivity growth in the beef sector of 2.21 per cent in the 1990s. Similarly, a total factor productivity growth rate of 3 per cent was projected by Ludena et al. (2007) for the period 2001 to 2040. Also, productivity in China's milk sector increased since the 1960s. The OECD FAO (2012) estimated that between 1961 and 1979 the partial factor productivity growth rate was 2 per cent annually which dropped by 1 per cent between 1980 and 1999. However, between 2000 and 2009, the productivity in the milk sector increased significantly with a growth rate of 5 per cent annually. In their study, Rae & Hertel (2000) projected a small annual partial factor productivity growth rate of 0.2 per cent in the milk sector for the period of 1995 to 2005.

Table 2.15: Partial and total factor productivity growth rates in China's meat and dairy sector, annual percentage change.

Source	Period	Ruminants		Non-ruminants		Dairy
		Beef	Sheep meat	Pig	Poultry	Milk
Rae & Hertel (2000)(2)	1995 – 2005^{P}	4.2(1)		4.9(1)		0.2
	1991 -97			3.0	11.8	
	1961 – 97			4.2	2.9	
Nin et al. (2004)(2)	1995 – 2010^{P}			3.9	9.5	
Rae et al. (2006)(3)	1990-1999	2.21				1.31
Ludena et al. (2007)(3)	2001 - 2040	3.01		6.6		
OECD FAO (2012)(2)	1985 – 2011	8.5	5.3	3	3.2	
	2012 – 2021^{P}	4.9	3	1.7	1.8	
	1961- 79					1.5
	1980 – 99					-1.3
	2000-2009					4.8

Symbol: P = projected
Notes: (1) China and Taiwan.
(2) Partial factor produtivity growth rates.
(3) Total factor produtivity growth rates.

2.3.3 Agricultural trade in China

China is one of the largest trading countries in the world (FAOSTAT, 2012b). Table 2.16 presents China's trade flows by commodity in million US Dollars between 1961 and 2010. In 2010, Chinese agricultural exports were valued at US$36 billion. The main agricultural exports were fruit and vegetables, milk and pulses; and China's main agricultural imports were oilseeds, vegetable oils and fruit and vegetables. Between 1961 and 2010, agricultural exports increased by almost the same percentage as total merchandise exports. During that period, export commodities with significant growth rates were milk, fruit and vegetables, oilseeds and cereals. Similarly, meat exports increased significantly between 1961 and 2001, however they have decreased by 6 per cent between 2001 and 2010. Likewise, exports of cereals showed substantial growth rates between 1961 and 2001 but dropped by 40 per cent between 2001 and 2010. Between 1961 and 2010 China's agricultural imports increased constantly which shows that China has become increasingly an agricultural net importer. High growth levels were recorded for meat, fruit and vegetables and vegetable oils. Additionally, there has been a large increase in oilseeds for animal feed.

Table 2.17 shows China's major trading partners of dairy and meat commodities in 2010 with imports mainly coming from Australia and New Zealand. Chinese exports of meat products were mainly sent to Japan while dairy products were mainly sent to Asian countries such as Vietnam and the Phillipines (FAOSTAT, 2012b).

Projections for trade flows of agricultural commodities from the OECD FAO Agricultural Outlook 2012 – 2021 indicate that beef and veal exports will slightly decrease by 2021 while beef and veal imports will increase more than 40 per cent for the same period. With regards to dairy exports, the highest growth is projected for WMP exports which are expected to increase significantly by 2021. Interestingly, China's cheese imports are projected to double between 2012 and 2021, and imports of SMP are expected to increase by 24 per cent. Also, China's wheat imports are predicted to slightly increase by 2021 while wheat exports are expected to decrease almost 1 million tonnes by 2021, this represents a drop of 13 per cent during the same period (OECD FAO, 2012).

Table 2.16: China's trade flows by commodity in US$ million, 1961 – 2010.

Trade Flow	Commodity	1961	1971	1981	1991	2001	2010
Imports	Animal fats	6	9	52	52	114	308
	Cereals	465	335	3,890	2,557	1,541	3,072
	Vegetable oils	6	17	107	747	689	8,444
	Fruit & veg.(1)	3	11	130	375	1,240	5,239
	Oilseeds	21	70	571	573	3,810	27,663
	Pulses	1	3	44	24	58	307
	Meat(2)	0	0	50	230	725	2,179
	Milk(3)	3	16	128	277	296	1,635
	Agricultural products	**760**	**808**	**8,195**	**9,429**	**16,396**	**81,415**
	Merchandise trade	**1,750**	**4,055**	**43,081**	**126,651**	**351,524**	**1,646,335**
Exports	Animal fats	-	-	0	4	11	46
	Cereals	20	190	288	1,111	1,117	667
	Vegetable oils	11	19	82	150	107	199
	Fruit & veg.(1)	85	402	1,217	2,497	3,982	15,921
	Oilseeds	44	67	307	742	463	709
	Pulses	9	18	71	239	281	837
	Meat(2)	-	1	3	15	30	28
	Milk(3)	12	125	433	1,855	1,348	2,323
	Agricultural products	**381**	**1,347**	**4,483**	**11,624**	**12,993**	**36,164**
	Merchandise trade	**1,690**	**4,700**	**44,501**	**148,088**	**392,412**	**1,852,425**

Notes:
(1) This includes fruit and vegetables.
(2) Meat includes bovine meat, pig meat and poultry meat.
(3) Milk includes dry milk and fresh milk.
Source: FAOSTAT (2012b).

Table 2.17: China's major trading partners of meat and dairy commodities, 2010.

Trade Flow	Commodity	Major trading partners
Imports	Beef and veal	Australia, US
	Pig meat	Canada, US
	Poultry meat	Argentina, Brazil, US
	Sheep meat	Australia, New Zealand
	Butter	Australia, New Zealand
	Cheese	Australia, New Zealand
	SMP	Australia, New Zealand
	WMP	Netherlands, New Zealand
Exports	Beef and veal	Japan, Russia
	Pig meat	Japan
	Poultry meat	Japan, Vietnam
	Sheep meat	Jordan, UAE
	Butter	Egypt, Iran
	Cheese	Vietnam
	SMP	Philippines
	WMP	Myanmar, Venezuela

Source: FAOSTAT (2012b).

2.3.4 China's trade policy

China's international trade has expanded steadily since 1979. The process began relatively slowly in the 1980s after successive liberalisation of complex trade controls but accelerated in the 1990s with broader trade reforms required for WTO accession. These reforms included the gradual reduction of tariff and non-tariff barriers (e.g., drops in tariffs on all agricultural products to 10 per cent by 2005), the removal of export subsidies and the reduction of the state monopoly on exports (Rumbaugh & Blancher, 2004). For example, between 1995 and 1997 China cut its import duties on many goods[5] but maintained high tariffs on others, particularly on agricultural products (Rumbaugh & Blancher, 2004).

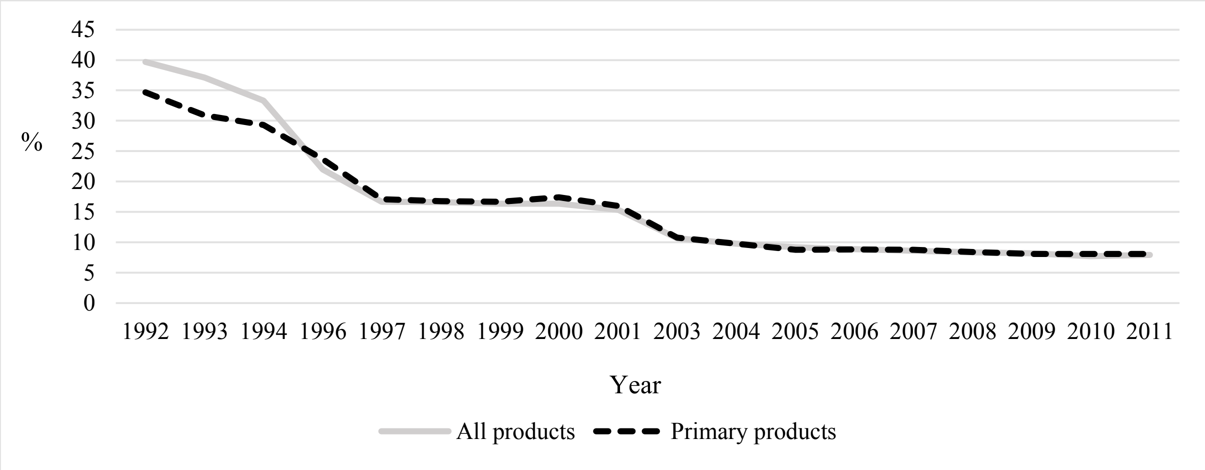
China first applied to GATT in 1986, negotiations took 15 years and were finalised when the US and China agreed to terms on China's entry into the WTO with the establishment of permanent normal trade relations in the Sino-US WTO deal in Beijing on 15, November 1999, however full accession was received on 11 December 2001 (WTO, 2012c; Rumbaugh & Blancher, 2004).

Under WTO membership and as part of the implementation process China's trade regime became increasingly tariff-based as it agreed to eliminate import quotas, licenses, designated

[5] Prior to WTO accession, China never published complete import quota regulations or a description of its import quota system.

trading practices and other non-tariff barriers. Moreover, the substitution of import quotas with tariff-rate quotas for some agricultural commodities increased the transparency of the trade regime (Rumbaugh & Blancher, 2004). Figure 2.4 shows the average tariff rate of all products and of primary products in China between 1992 and 2011. It can be seen that before entering the WTO, the average tariff level for all imports in 1992 was as high as 40 per cent for all products and 35 per cent for primary products. At WTO accession in 2001, the tariff rate was reduced to 15 per cent for all products, and in 2011 it was at 8 per cent.

Figure 2.4: Simple average tariff rate of all products and primary products in China, 1992 – 2011.



Note: Tariffs for the years 1995 and 2002 were not available.

Source: World Bank (2011b).

With the accession to the WTO fundamental changes to China's legal and regulatory frameworks at the national government level have been made to comply with WTO principles. For example, the foreign direct investment regime has been extensively upgraded with the removal of requirements associated with foreign currency financing, and local content or export performance (Rumbaugh & Blancher, 2004). China's integration to the WTO has also obligated China to comply with the rules for the WTO's dispute settlement process.

Over recent years, China increased its number of bilateral trade agreements. In 2008, New Zealand, as the first OECD economy, signed a comprehensive Free Trade Agreement (FTA) with China. Negotiations took place over a period of four years and the agreement went into force in October 2008. Before the FTA came into force New Zealand exporters faced tariffs between 10 and 20 percent. The FTA between China and New Zealand provides for the removal of tariffs on 96 per cent of traded goods over a 12-year-period, fully coming into force in 2019. (MFAT, 2008). Table 2.18 shows Chinese tariffs for New Zealand meat and dairy products in 2008 and 2013; in addition, the year of complete removal of the Chinese tariff as stated in the

FTA is indicated. In 2008, the tariff rate for lamb was 13.3 per cent while beef was tariffed at 10.7 per cent. The tariff rate for cheese was 10.8 per cent while dairy powders were tariffed 9.2 per cent (New Zealand – China Free Trade Agreement, 2008). In 2013, tariffs for beef and sheep commodities were 5 per cent and 4 per cent, respectively (New Zealand – China Free Trade Agreement, 2008) and both will be completely eliminated in 2016 (MFAT, 2008). In 2013, tariffs for dairy commodities were around 5 per cent (New Zealand – China Free Trade Agreement, 2008). In 2017, tariffs on key dairy products such as butter, cheese and milk will be completely removed; total tariff elimination of dairy powders will be achieved in 2019 (MFAT, 2008). Total tariff removal will equate to an annual duty saving of NZ$116 million. Additionally, the FTA provides rules to determine which goods qualify for tariff removal as well as rules to deal with unfair trade or unexpected surges in imports from the other country (MFAT, 2008).

Table 2.18: Chinese tariffs for New Zealand meat and dairy products in 2008 and 2013 in per cent and year of complete tariff elimination based on the New Zealand-China FTA.

Commodity	2008	2013	Year of complete tariff elimination
Lamb	13.3	5	2016
Beef	10.7	4	2016
Butter	9	4	2017
Cheese	10.8	4.8	2017
WMP	9.2	5	2019
SMP	9.2	5	2019

Source: adapted from New Zealand - China Free Trade Agreement (2008).

The FTA also covers services, including education and environmental services. Finally, the FTA includes the movement of people between both countries. For New Zealand, it facilitates the travel of business people to and from China and provides access to skilled workers from China in certain areas where long-term skills shortages exist (MFAT, 2008).

In recent years, China has signed further FTAs with Chile, Switzerland, Iceland, Singapore and others, and is in negotiations towards FTA with several other countries such as Australia and Norway (China FTA Network, 2012).

To summarise, in the process of China's WTO accession China has liberalised trade and opened its economy to trade and foreign investment. Since then, China has concentrated on negotiating bilateral free trade agreements (e.g., New Zealand-China FTA) which cause a shift in China's bilateral trade balances.

2.3.5 Agricultural GHG emissions in China

China is the world's largest emitter of GHG emissions and agricultural GHG emissions have grown significantly since 2000 (FAOSTAT, 2013). Agricultural GHG emissions represent 20 per cent of China's total emissions (Huang & Jingjing, 2012; UK-China Sustainable Agriculture Innovation Network, 2011). In 2010, China's agricultural sector generated 664 million tonnes of CO_2 which was an increase of 12 per cent from the year 2000 (FAOSTAT, 2013).

A large share in agricultural GHG emissions comes from enteric fermentation. In 2010, enteric fermentation in livestock released 160 million tonnes of CO_2- equivalents which accounted for 24 per cent of the total agricultural GHG emissions (CO_2-equivalent) in China. Nine per cent of all agricultural GHG emissions were generated by manure management (FAOSTAT, 2013).

Livestock production in China has been increasing (see Section 2.3.2) and consequently GHG emissions from the livestock sector have been rising. Table 2.19 illustrates China's GHG emissions (in CO_2-equivalents) from different livestock types between the decades 1990-2000 and 2001-2010. It can be seen that GHG emissions from most livestock increased during that period with large increases generated by dairy and sheep.

Table 2.19: GHG emissions (in CO_2-equivalents) from enteric fermentation and manure management by livestock type in China in million tonnes, 1990 - 2010.

Type	1990-2000	2001-2010
Dairy cattle	69.76	161.46
Non-dairy cattle	962.16	781.43
Pigs	276.12	276.15
Sheep	138.93	148.49

Source: FAOSTAT (2013).

2.4 Changes in India

India's population is growing rapidly. With a population of 1.2 billion people in 2012 (World Bank, 2012c) and a projected growth rate of 35 per cent by 2050 (UN, 2012), India is also one of the fastest growing economies in the world. In 2012, India's GDP per capita was US$1,489, with an increase of 2 per cent to the previous year (World Bank, 2012a). Actual GDP was US$ 1.8 trillion with a growth rate of 3 per cent to the previous year. It is projected to grow by 6 per cent annually to 2016 (World Bank, 2012a). While the agricultural sector accounts for only 17 per cent of India's GDP, it employs approximately 60 per cent of the population (NZTE, 2011b).

The Indian diet is traditionally a more vegetarian-based diet and until the late 1980s per capita meat consumption levels in India were less than 5 kg per year (Smil, 2002; FAOSTAT 2012a; Delgado, 2003). Since 1990, India's overall food consumption has increased and is accompanied by changes in dietary patterns towards more livestock products (see Appendix A). In this section, India's food consumption, production and trade figures for selected agricultural commodities will be given. This is followed by a description of India's trade policies. The section finishes with an outline of India's agricultural GHG emissions, particularly from livestock.

2.4.1 Food consumption in India

The level of food consumption in India is growing, and in particular the consumption of livestock products (FAOSTAT, 2012a). Table 2.20 shows India's food consumption[6] by category between 1961 and 2009. It can be seen that 174 million tonnes of cereals, 87 million tonnes of milk and 60 million tonnes of fruits were consumed in 2009. In contrast, eggs had the lowest consumption with only 2.7 million tonnes consumed in 2009. Between 1961 and 2009, aggregated milk consumption in India increased 5-fold and meat consumption more than tripled. The smallest increase was recorded for cereal consumption which only doubled in that period.

[6] This is food availability for human consumption (FAOSTAT, 2012a).

Table 2.20: Food consumption by category in India in million tonnes, 1961 – 2009.

Category	1961	1971	1981	1991	2001	2009
Cereals	63.43	79.24	105.22	142.70	155.41	173.60
Fruits	11.76	14.61	18.11	24.64	38.18	59.84
Oilcrops	2.50	3.20	2.95	6.10	6.67	8.54
Pulses and roots	15.12	18.98	22.78	29.19	35.90	50.82
Vegetable oils	1.84	2.36	3.81	5.77	7.93	10.45
Animal fats	0.46	0.47	0.73	1.13	2.39	3.26
Eggs	0.14	0.27	0.52	1.03	1.83	2.76
Meat	1.70	2.07	2.65	3.80	4.27	5.34
Milk	17.48	19.56	29.28	45.80	66.08	87.26

Source: FAOSTAT (2012a).

Projections show that food consumption in India is expected to continue to grow, particularly the consumption of meat and dairy products. As shown in Table 2.21, between 2012 and 2021 the highest increase is predicted for cheese consumption which is expected to increase by 53 per cent – albeit starting from a very low level. During the same period, milk consumption is projected to increase by 43 million tonnes by 2021, accounting for an increase of 35 per cent (OECD FAO, 2012). Similarly, beef and sheep meat consumption is projected to increase by almost 30 per cent by 2021.

Table 2.21: Projections of meat and dairy consumption in India in kilotonnes, 2012 and 2021.

Commodity	2012	2021	Percentage change 2012 - 2021
Beef and veal	1,970.98	2,497.90	27%
Pigmeat	495.27	577.62	17%
Poultry meat	2,873.53	4,400.85	53%
Sheep meat	676.18	886.63	31%
Milk	123,377.82	166,919.16	35%
Butter	4,499.36	6,070.76	35%
Cheese	0.20	0.31	53%
SMP	214.68	234.99	9%
WMP	11.23	17.33	54%

Source: OECD FAO (2012).

Table 2.22 provides a summary of various estimates of income elasticities of demand in India. The majority of these show that meat commodities in India are normal goods. In contrast, milk was estimated to be a luxury good by two studies (see Mittal, 2006; Kumar, Kumar, Parappurathu & Raju, 2011) while Kumar, Mruthyunjaya and Birthal (2007) and Rosegrant et al., (2001) estimated milk as a normal good.

Table 2.22: Income elasticities of demand for meat and milk products in India.

Source	Milk	Meat	Beef	Mutton/ sheep Meat	Pork	Poultry
Kumar et al. (2007)	0.59	0.89(1)				
Kumar et al. (2011)	1.64					
Mittal (2006)	1.19	1.3(1)				
Rosegrant et al. (2001)(2)	0.58		0.63	0.58	0.58	0.96

Notes:
(1) This is composed of meat, fish and egg.
(2) Projected elasticities by 2020.

2.4.2 Food production in India

With India's food consumption having largely increased since the 1960s, agricultural production has been also increasing. Table 2.23 shows India's food production by category between 1961 and 2009. In 2009, India produced 111 million tonnes of milk, 204 million tonnes of cereals and 6 million tonnes of meat. Between 1961 and 2009 India's food production more than tripled recording high increases in milk production (increased more than 5-fold) and meat production (more than tripled). Other food categories that experienced high growth levels in that period were eggs and vegetable oils. In contrast, the production of cereals and pulses and roots had low growth rates between 1961 and 2009.

Table 2.23: Food production by category in India in million tonnes, 1961 – 2009.

Category	1961	1971	1981	1991	2001	2009
Cereals	69.56	91.73	120.98	155.79	196.38	204.29
Fruits	13.37	16.65	21.00	28.46	44.35	70.36
Oilcrops	11.02	14.85	16.55	26.85	29.76	42.64
Pulses and roots	18.81	23.11	27.87	36.16	42.20	59.29
Vegetable oils	2.15	2.84	3.62	5.79	5.88	8.04
Animal fats	0.53	0.56	0.82	1.27	2.53	3.44
Eggs	0.17	0.31	0.60	1.21	2.15	3.32
Meat	1.70	2.07	2.71	3.89	4.52	5.96
Milk	20.38	22.50	34.30	54.06	83.42	110.94

Source: FAOSTAT (2012a).

India's production of meat and dairy commodities is projected to increase in the future. Table 2.24 shows projections for the production of meat and dairy commodities estimated by the OECD FAO (2012). For the projection period, the highest increase is projected for dairy products, particularly the production of WMP is expected to more than double by 2021 while milk and butter production is projected to increase by 35 per cent, each. Almost three-quarters of all additional butter produced globally is expected to come from India and Pakistan; New Zealand and the US is expected to contribute another 10 per cent (OECD FAO, 2012). Similarly, India's beef and veal production is expected to increase by almost 25 per cent by 2021.

Table 2.24: Projections of meat and dairy production in India, in kilotonnes, 2012 and 2021.

Commodity	2012	2021	Percentage change 2012 - 2021
Beef and veal	2,781.79	3,458.89	24%
Pigmeat	495.09	577.48	17%
Poultry meat	2,875.64	4,403.08	53%
Sheep meat	748.12	930.63	24%
Milk	122,526.64	165,632.33	35%
Butter	4,499.81	6,076.29	35%
Cheese	0.83	0.44	-47%
SMP	211.85	271.21	28%
WMP	3.39	7.50	121%

Source: OECD FAO (2012).

Table 2.25 shows past and projected partial and total factor productivity growth rates for India's meat and dairy sector. Between 1985 and 2011 the highest partial factor productivity rate was recorded for the poultry sector which grew by 7.5 per cent annually (OECD FAO, 2012). In the same period, productivity in India's beef sector increased annually by 0.5 per cent. The growth in meat production is projected to continue – albeit slowly - the OECD FAO (2012) estimated that productivity in the beef sector will grow by 0.2 per cent annually between 2012 and 2021. In contrast, Ludena et al. (2007) projected an annual total factor productivity growth rate of 1.5 per cent of the meat sector in South Asia (including India) between 2001 and 2040. Likewise, productivity in India's milk sector increased since 1960. Between 1980 and 1999 the annual partial factor productivity growth rate was 3 per cent which has slowed down between 2000 and 2009 with an annual growth rate of 2.2 per cent (OECD FAO, 2012).

Table 2.25: Partial and total factor productivity growth rates in India's meat and dairy sector, annual percentage change.

Source	Period	Ruminants		Non-ruminants		Dairy
		Beef	Sheep meat	Pig	Poultry	Milk
Ludena et al. (2007)[2]	2001 – 2040[P]	1.48[1]		3.48		
OECD FAO (2012)[3]	1985 – 2011	0.5	0.1	0.3	7.5	
	2012 – 2021[P]	0.2	0.0	0.2	4.2	
	1961– 1979					1.2
	1980 – 1999					2.9
	2000 – 2009					2.2

Symbol: P – projected
Note: (1) South Asia Region
(2) Total factor produtivity growth rates.
(3) Partial factor produtivity growth rates.

2.4.3 Agricultural trade in India

India is a growing trading partner for agricultural commodities for many countries. Table 2.26 shows India's trade flows for selected agricultural products between 1961 and 2010. In 2010, India's agricultural exports, worth US$20 billion, accounted for 8.6 per cent of all Indian exports. The main agricultural export commodities were cereals, fruit and vegetables and meat while vegetable oils, fruit and vegetables, and pulses were the main imports in 2010. It can be seen that all agricultural exports increased significantly between 1961 and 2010. Cereals, meat and milk exports recorded significant growth rates over that period while animal fats recorded the smallest growth. Similarly, India's agricultural imports increased significantly between 1961 and 2010. In particular, agricultural imports more than tripled in the last decade. Large increases were recorded for imports of pulses, vegetable oils and fruit and vegetables while imports of cereals and animal fats decreased between 1961 and 2010.

Table 2.26: India's trade flows by commodity in US$ million, 1961 – 2010.

Trade Flow	Commodity	1961	1971	1981	1991	2001	2010
Imports	Animal fats	2	22	54	0	1	1
	Cereals	344	241	197	5	1	63
	Vegetable oils	9	29	644	104	1,448	4,782
	Fruit and vegetables	38	57	111	273	1,050	2,439
	Oilseeds	20	16	9	8	2	42
	Pulses	-	1	62	122	737	1,351
	Meat(1)	14	16	80	1	1	89
	Milk(2)	0	-	1	-	0	3
	Agricultural products	**633**	**603**	**1,445**	**742**	**3,923**	**10,407**
	Merchandise trade	**2,348**	**2,432**	**15,667**	**19,619**	**51,960**	**350,234**
Exports	Animal fats	-	0	-	-	0	3
	Cereals	-	4	447	372	1,072	2,940
	Vegetable oils	10	9	51	69	159	639
	Fruit and vegetables	56	101	336	465	872	2,341
	Oilseeds	11	9	55	46	211	911
	Pulses	1	5	1	16	83	193
	Meat(1)	1	-	51	78	256	1,706
	Milk(2)	-	-	0	4	35	63
	Agricultural products	**551**	**703**	**2,698**	**2,796**	**5,234**	**19,933**
	Merchandise srade	**1,395**	**2,045**	**8,373**	**18,057**	**44,293**	**219,670**

Notes:

(1) Meat includes bovine meat, pig meat and poultry meat.
(2) Milk includes dry milk and fresh milk.

Source: FAOSTAT (2012b).

Table 2.27 shows India's major trading partners for dairy and meat commodities in 2010. It can be seen that pig meat is mainly imported from Sri Lanka while New Zealand and Australia were major sources of dairy products in 2010. Data on beef imports was not available, however imports are likely to be non-existent or very small based on India's low per capita beef consumption for religious reasons. India's dairy and meat exports were predominantly sent to countries in the Middle East such as Saudi-Arabia and the United Arab Emirates (UAE).

India's trade is projected to grow. Projections of trade flows of agricultural commodities are provided by the OECD FAO Agricultural Outlook 2012 – 2021. It is expected that beef and veal exports will increase slightly by 2021. With regards to dairy exports, the highest growth rate is projected for SMP exports, doubling by 2021. Contrarily, exports of WMP and cheese are projected to slightly decrease by 2020.

Table 2.27: India's major trading countries for meat and dairy commodities, 2010.

Trade Flow	Commodity	Major trading partners
Imports	Beef and veal	*
	Pig meat	Sri Lanka, Netherlands
	Poultry meat	Netherlands, UAE
	Sheep meat	Netherlands, New Zealand
	Butter	New Zealand
	Cheese	Italy, New Zealand
	SMP	Australia, New Zealand
	WMP	New Zealand
Exports	Beef and veal	Egypt, Jordan, Malaysia, UAE
	Pig meat	Vietnam, Myanmar
	Poultry meat	Saudi Arabia
	Sheep meat	Saudi Arabia, UAE
	Butter	Egypt, UAE
	Cheese	UAE
	SMP	Bangeladesh, UAE
	WMP	Bangeladesh, UAE

Symbol: * no data available.

Source: FAOSTAT (2012b).

2.4.4 India's trade policy

India was one of the few third world founding members of the GATT in 1947 and the WTO in 1995, and has actively participated in subsequent rounds of negotiations in Geneva (Henry, 2008; World Bank, 2011a). In the Doha negotiations for example, India was predominantly interested in advocating the idea of a Special and Differential Treatment which describes preferential provisions that apply only to developing and least developed countries allowing them to exempt themselves from the commitments made by developed countries.

Despite that, until the early 1990s it has been argued that India was one of the most closed economies globally, pursuing a defensive and protective trade policy to ensure the country's independent development (Henry, 2008). India pursued a complicated and highly regulated trade regime with high tariffs, severe quantitative restrictions, complex licensing schemes and state trading. In July 1991, India liberalised its trade policies and started to continuously open up its economy to involve trade and to drive economic growth (Henry, 2008). These reforms were notable for the elimination of the restrictive licensing regime on imports and exports, reducing basic tariffs, reducing quantitative restrictions on imports and exports, removing export subsidies and radically changing the transactions regime (Balasubramanyam, 2003). However, India's share in world trade is relatively small, whether measured by exports or imports, and despite those reforms and the reduction of tariffs on many products, India's tariffs continue to be relatively high. Table 2.28 shows the average tariff rate of all products and of primary products in India for selected years. In 2009, the average applied tariff for all products was 11.5 per cent while primary products were tariffed 20 per cent. India also has an indirect tax levied on goods that are exported out of India (Customs Act 1962).

Table 2.28: Simple average tariff rate of all products and primary products in India for selected years.

Year	1990	1992	1997	1999	2001	2004	2005	2008	2009
All products	81.6	56.4	28.9	32.5	31.9	29	17	10	11.5
Primary products	71.6	51.5	27.8	30.6	32.3	30.7	25	19.7	20

Source: World Bank (2011b).

Other significant changes in India's trade regime occurred in 2002 within the Trade Policy Review by the WTO. This resulted in the removal of quantitative import restrictions from 714 import items, and there have been significant efforts to rationalise the tariff but it remained complex and relatively high. One reason for India's high tariffs is that they have been for a long time the major source of government revenues and contribute a large amount to net tax revenues of India's Government (Balasubramanyam, 2003). Thus, it is argued that the 2002 initiated removal of import quantitative restrictions and assorted export incentives did not amount to trade liberalisation.

With regards to regional policies, until the early 2000s India did not join negations in regional policy agreements, and it did not join any of the various regional groupings that were starting to emerge, e.g., the Asia-Pacific Economic Community (APEC) or the Asia- Europe Meeting (ASEM). However, since then India's government is becoming more active in seeking out bilateral trade agreements, mainly with other developing countries. It has for example limited FTAs with Sri Lanka and Thailand, preferential trade agreements (tariff concession schemes) with several other countries and a Comprehensive Economic Cooperation Agreement with Singapore. Additionally, India and the ten member states of the Association of Southeast Asian Nations (ASEAN) in 2009 developed the ASEAN–India Free Trade Area (AIFTA) in 2009 (WTO, 2012b).

Furthermore, India is currently engaged in several trade negotiations. This includes the Doha Round at the WTO, and there are negotiations towards bilateral FTAs with the European Union, Japan, New Zealand and other South Asian countries, among others (Polaski, Ganesh-Kumar, McDonald, Panda & Robinson, 2008). For example, in September 2014 the ASEAN – India

FTA on services and investment was signed (The Economic Times, 2014, September 9). Negotiations for a comprehensive FTA with the EU are ongoing since June 2007 and after the EU-India Summit in early 2012 negotiations were strengthened (European Commission [EC], 2013).

Negotiations towards a bilateral free trade agreement with New Zealand started in 2010, and in July 2013 New Zealand hosted the ninth round of the negotiations (MFAT, 2013). The New Zealand Government implemented an inter-agency NZ Inc. India strategy that is working towards India being a core trade, economic and political partner for New Zealand by 2015. The strategy aims to grow merchandise exports and services trade (MFAT, 2012). However, there are already numerous bilateral agreements in force between New Zealand and India covering a range of areas such as air services and wool imports. Additionally, bilateral arrangements between both countries exist in the areas of agriculture, plant quarantine, information technology, science and technology, education and film (MFAT, 2012). Furthermore, multilateral engagement between New Zealand and India occurs in the UN, Commonwealth, the WTO and other forums (MFAT, 2012).

2.4.5 Agricultural GHG emissions in India

India is the second largest emitter of GHG emissions in the world with large proportions generated by the agricultural sector. In 2010, India's agricultural sector generated 609 million tonnes of CO_2 which is an increase of 15 per cent from the year 2000 (FAOSTAT, 2013).

A large share of agricultural GHG emissions is generated by enteric fermentation from livestock. In 2010, enteric fermentation in livestock released 301 million tonnes of CO_2-equivalent. This accounted for 49 per cent of the total agricultural GHG emissions (in CO_2-equivalent). In contrast, manure management emitted 24 million tonnes of CO_2- equivalent which is 4 per cent of all agricultural GHG emissions in India (FAOSTAT, 2013).

As mentioned in Section 2.4.2, in recent years livestock production has grown in India and so did GHG emissions from this sector. In 2010, GHG emissions from non-dairy cattle accounted for 31 per cent of all GHG emissions from animals from enteric fermentation in India. Eighteen per cent of GHG emissions from enteric fermentation came from dairy and sheep contributed 3 per cent. Table 2.29 shows India's GHG emissions (in CO_2-equivalents) from different livestock types from enteric fermentation and manure management between the decades 1990-2000 and 2001-2010. It can be seen that GHG emissions from most livestock increased over both decades with large increases particularly recorded for sheep and dairy.

Table 2.29: GHG emissions (in CO_2-equivalents) from enteric fermentation and manure management in India, in million tonnes, 1990 – 2010.

Livestock type	1990-2000	2001-2010
Dairy cattle	470.67	493.67
Non-dairy cattle	1,049.93	901.08
Pigs	17.97	14.96
Sheep	64.82	72.73

Source: FAOSTAT (2013).

2.5 Chapter Summary

This chapter focused on the increase in consumption and production of meat and dairy products in developing countries such as India and China as a consequence of population growth, urbanisation and rising incomes. The history and future trends of increased livestock product consumption and production in China and India were discussed as well as the countries' trade policies. It was shown that these changes will have impacts on international trade and the environment. In particular, the increase in meat and dairy consumption and production is likely to effect the amount of GHG emissions from agriculture. Thus, the chapter examined trade flows and agricultural GHG emissions in India and China.

As shown in this chapter and in Chapter 1, New Zealand's agricultural trade to these countries is increasing. In particular, trade with China has been growing significantly in recent years which may be related to the FTA that came into force in 2008 with tariff elimination still ongoing. Agricultural trade with India has the potential to increase in the future based on current negotiations towards a FTA. This chapter showed that New Zealand GHG emissions from livestock are high and might increase further from the increase in meat and dairy consumption as well as from different trade policies in China and India. The following section of the thesis will explore the theory and literature in the area of trade and the environment.

Chapter 3
Trade theory

3.1 Introduction

The previous chapter described trends in food consumption, production and trade patterns particularly in China and India and also examined possible changes in agricultural GHG emissions resulting from these changes. This chapter will outline the theory of trade and gains from trade. Then the partial equilibrium model is used to show the impacts of different types of trade restrictions. The chapter finishes with a description of the relationship between trade and the environment and outlines the theory of agricultural GHG emissions.

3.2 Trade theory

International trade theory describes the complex patterns of the exchange of goods and services across countries. It analyses the fundamentals of this exchange and its gains for the trading countries (Mankiw, 2007).

Countries trade for several reasons with the most obvious reason being that countries are different from each other. They have different resource endowments or lack the availability of a resource completely. These resources can be natural resources, human resources, capital and technology (Krugmann & Obstfeld, 1997). Adam Smith (1776) noted that for two countries to voluntarily trade with each other, both countries must gain. He argued that if one country did not gain or even lost, the country would not trade. According to Adam Smith, trade between two countries is based on the absolute cost advantage that one country has over the other. When one country is more efficient than (or has an absolute advantage over) another country in producing a commodity but is less efficient than (or has an absolute disadvantage over) the other country in producing a second commodity, then both countries can gain by each specialising in the production of the commodity where its absolute advantage lies and trading a part of its output with the other country for the commodity where its absolute disadvantage lies. In this case, both countries utilise their resources most efficiently, and the output of both commodities could grow (McLaren, 2013; Mankiw 2007; Salvatore, 2005).

3.2.1 The Ricardian trade theory

The theory of absolute advantage was expanded by David Ricardo (1817) with his theory of comparative advantage. The law of comparative advantage states that if one country is less efficient than (has an absolute disadvantage over) another country in the production of both commodities, there is still basis for mutually beneficial trade. The country should then specialise in the production of and export the commodity in which the costs of its production are relatively lower and import the commodity in which the relative costs of its production are higher (Todaro & Smith, 2009; Salvatore, 2005). Consequently, it will gain from foreign trade. Thus, Ricardo argued that the nation with the lower opportunity cost[7] in the production has a comparative advantage in that commodity. A country would export the commodities for whose production it had lower opportunity costs than other countries. Thus, both nations can indeed gain by each specialising in the production and export of the commodity of its comparative advantage (Salvatore, 2005).

Briefly, the Ricardian model of trade rests on the following assumptions:

- Two countries are trading.
- Only two goods are produced.
- Labour is assumed to be the only factor of production.
- The model has been developed in a general equilibrium framework.
- Labour is homogenous within the domestic boundaries, though its productivity varies across the nations.
- Goods that are produced are considered to be homogenous across the countries.

By applying the principle of comparative advantage, all countries can benefit from trading because trade allows each country to specialise in doing what it does best (Todaro & Smith, 2009; Krugman & Obstfeld, 1997). In doing so, a country can achieve the economies of scale in production. This means a country produces only a limited number of goods and can produce those on a larger scale and to lower marginal costs (Krugman & Obstfeld, 1997).

Although the Ricardian theory could determine the limits in which the terms of trade would take place, the theory failed to determine the actual terms of trade because Ricardo only took into account the supply side of the trade model. However, in order to determine the terms of trade it is necessary to take into account both the supply and the demand side of a market (Salvatore, 2005). The terms of trade are defined as the ratio of the price index of a nation's export to its import commodities, i.e., what quantity of imports can be purchased through the sale of a fixed quantity of exports (Todaro & Smith, 2009). A number of measures of the terms of trade have been suggested by the economists Mill (1920) and Marshall (1933).

[7] The opportunity cost of an item is what has to be given up to acquire that item (Mankiw, 2007).

In 1920, Mill introduced his theory of reciprocal demand which is one of the earliest examples of general equilibrium analysis in trade theory (Salvatore, 2005). He claimed that

> *"the exports and imports between the two countries (or, if we suppose more than two, between each country and the world) must in the aggregate pay for each other, and must therefore be exchanged for one another at such values as will be compatible with the equation of the international demand (Mill, 1920)".*

Thus, Mill (1920) developed the equation of international demand according to which the terms of trade are determined as to equate the value of exports and the value of imports (Zhang, 2008).

3.2.2 Heckscher-Ohlin theorem

Ricardo's theory of comparative advantage is based on labour productivity. He explained that differences between countries exist due to their use of different production technologies. Accordingly, the differences between relative commodity prices between two countries form the basis for trade (Salvatore, 2005). There have been various developments of Ricardos' theory of comparative advantage with the Heckscher-Ohlin (H-O) theorem being one of the most important (Todaro & Smith, 2009). In contrast to Ricardo, Heckscher (1919) and Ohlin (1933) focused on the difference in the relative abundance of production factors in countries as the most important determinant of the different relative commodity prices and comparative advantage of different countries. The H-O model is based on a long-term general equilibrium in which production technologies are identical in different countries but factor endowments in countries are different (Salvatore, 2005). These differences in factor endowments provide the basis of trade. Hence, a country will export the commodity whose production uses the country's relatively abundant and cheap resource and import the commodity whose production requires the intensive use of the country's relatively scarce and cost-intense resource. Simply put, a capital-abundant country must export capital-intensive products and labour-abundant countries must export labour-intensive commodities (Salvatore, 2005; Zhang, 2008). For this reason, the H-O approach to trade theory is often referred to as the factor-endowment approach (Kenen, 2000).

The H-O model was further developed by Stolper and Samuelson (1941). The Stolper-Samuelson theorem states that an increase in the relative price of one commodity increases the real return of the factor used intensively in the production process of that commodity and reduces the real return of the other factor. More generally, the theorem states that free international trade lowers the real income of a country's relatively scarce factor and increases the real income of the country's relatively abundant factor (Zhang, 2008; Kenen, 2000).

Following on from this was the factor-price equalization theorem by Lerner (1952) and Samuelson (1948). It states, if there were no trade barriers in place, trade would completely equalise factor prices between trading countries due to competition (Zhang, 2008; Kenen, 2000). The factor that receives the lowest price, before two countries integrate economically and effectively become one market, tends to become more expensive relative to other factors in the economy. In contrast, those factors with the highest price will tend to become cheaper (Samuelson, 1948). The factor-price equalization theorem argues that international trade will bring equalisation in the relative and absolute returns to homogenous factors across trading countries and would therefore compensate completely for the effects of differences in factor endowments. Both, relative and absolute factor prices are equalised in the trading nations (Salvatore, 2005; Kenen, 2000). The equalisation of relative and absolute factor prices between two countries as a result of free trade implies that the real income of labour and the real income of owners will decline in the nation with cheap labour and expensive capital. In contrast, the real income of labour and the real income of owners of capital will rise in the nation with expensive labour and cheap capital. Since in developed nations labour is the relatively scarce factor and capital the relatively abundant factor, international trade tends to lower the real income of labour and increase the real income of owners' capital (Salvatore, 2005).

Beyond those economic benefits of trade that are included in the standard trade analysis, Mankiw (2007) listed several other economic benefits of international trade. There is an increased variety of goods available to consumers and therefore increases consumers choices. Trade allows offering specialty goods from other countries to consumers on the domestic market, e.g., German beer in New Zealand or New Zealand lamb in Germany. Another benefit is that trade enables the production of large quantities for lower costs (i.e. economies of scale). Simply put some goods can only be produced at low costs if they are produced in large quantity. Thus, trade allows firms to access world markets and to realise economies of scale because a firm in a small country cannot take full advantage of the economies of scale if it only can sell its products in a small domestic market. Furthermore, with trade there is increased competition in the world markets. It is a type of market failure if a company has the market power to raise prices above competitive level (Mankiw, 2007). Trade fosters competition and companies/countries may develop a competitive advantage in a sector. The concept of Competitive Advantage is originally due to Michael E. Porter (1998). It states that an agent involved in trade has an advantage over its competitors through two main mechanisms: cost or differentiation (Porter, 1998). Thus, competitive advantage indicates that a sector with an advantage returns more value per unit than equivalent sectors in other countries. Finally, trade between countries allows for the enhanced flow of ideas, e.g., transfer of technology. The transfer of technological advances around the world is often thought to be linked to international trade in the goods that embody those advances (Mankiw, 2007).

To summarise, trade theory overall suggests that countries can achieve gains from trade. The next section will outline how the international marketplace can achieve gains from trade.

3.3 The gains from trade

Countries can gain from trade by specialisation in producing the commodity it has a comparative advantage in and then exchanging this for the commodity it has a comparative disadvantage in.

The concept of gains from trade can be explained using a production possibility frontier (PPF). The PPF is a curve that shows the alternative combinations of two commodities that a nation can produce by fully utilising all of its resources with the best technology available to it (Salvatore, 2005; Markusen & Melvin, 1998). The slope of the curve is the terms of trade. As mentioned above, these are defined as the ratio of the index price of a nation’s export to its import commodities (Todaro & Smith, 2009). In Figure 3.1, the PPF represents the supply side; the demand side is represented by the community indifference curve which shows different combinations of commodity quantities that would bring equal utility to the nation. A nation reaches equilibrium under autarky (i.e., no trade with other countries) where the PPF curve and the community indifference curve are tangent to one another and to the autarky price ratio (PA), as shown in point A. Hence, the equilibrium commodity price under autarky is given by the slope of the common tangent to the nation’s PPF and indifference curve at the autarky point of production and consumption (point A).

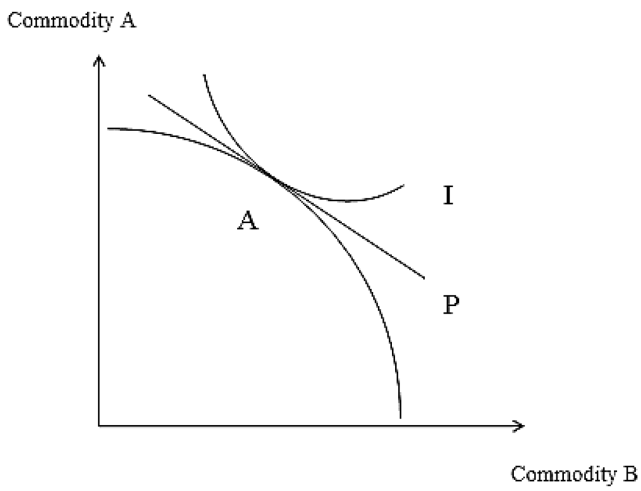
In order for a market to clear at this equilibrium point, there are three main underlying assumptions:

1) The consumers' marginal rate of substitution (MRS) (the slope of the indifference curve) must be equal to the price ratio (PA) if consumers maximise their utility. MRS is the amount of one commodity that a nation could give up in exchange for one extra unit of a second commodity and still remain on the same indifference curve.

2) The producer's marginal rate of transformation (MRT) must be equal to the price ratio (PA) if producers are competitive and maximising their profits. MRT is the amount of one commodity that a nation must give up to produce each additional unit of another commodity. This is another name for the opportunity costs of a commodity and is given by the slope of the PPF at the point of production.

3) The amount of each good produced should be equal to the amount consumed.

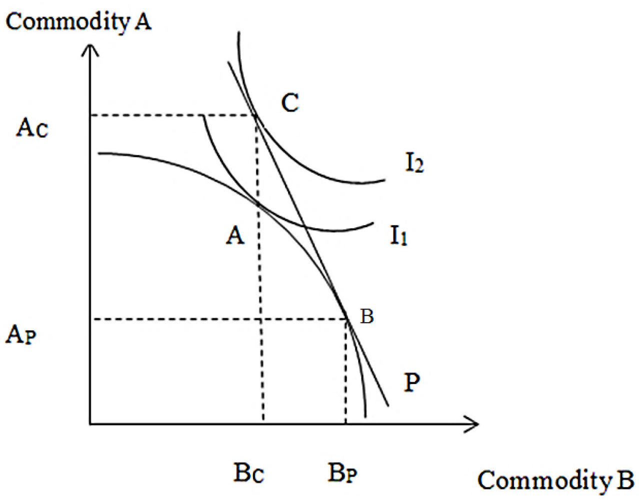
Figure 3.1: Equilibrium under autarky.



Source: Markusen & Melvin (1998).

Figure 3.2 illustrates the equilibrium under free trade. Countries can exceed the boundaries of their PPF through free trade. Under free trade, the price ratio is now determined by the world market, given by price line P in Figure 3.2, resulting in commodity B being more expensive in the international market than in the domestic market. Thus, domestic producers will reallocate resources from commodity A to commodity B until the production possibility point has moved to point B. At point B, the price line P is tangent to the PPF curve and the MRT in production is equal to the international terms of trade. Thus, at point B commodity B can be exported and commodity A can be imported in any combination along the price line P (Markusen & Melvin, 1998).

Figure 3.2: Equilibrium under free trade.



Source: Markusen & Melvin (1998).

In point C in Figure 3.2, the price line P is tangent to the highest possible indifference curve, this indicates the best point the country's consumers can achieve as the MRS in consumption is equal to the international terms of trade. Thus, the movement from indifference curve I_1 to indifference curve I_2 represents the gains from trade (Markusen & Melvin, 1998).

3.4 The partial equilibrium model of trade

Impacts of trade policies can be assessed using a partial equilibrium (PE) model. In a PE model the market for the good is analysed independently from prices and quantities in other markets. Hence, in partial equilibrium analysis, the effects of policy actions are examined through creating equilibrium only in the markets that are directly affected and ignoring effects that occur in other markets. The partial equilibrium approach to modelling trade has its limitations such as restricting analysis to a subset of commodities and keeping prices and demand for other commodities constant. However, this approach is extensively applied in the literature analysing trade (Suranovic, 2010).

The partial equilibrium model is usually based on the following main assumptions:

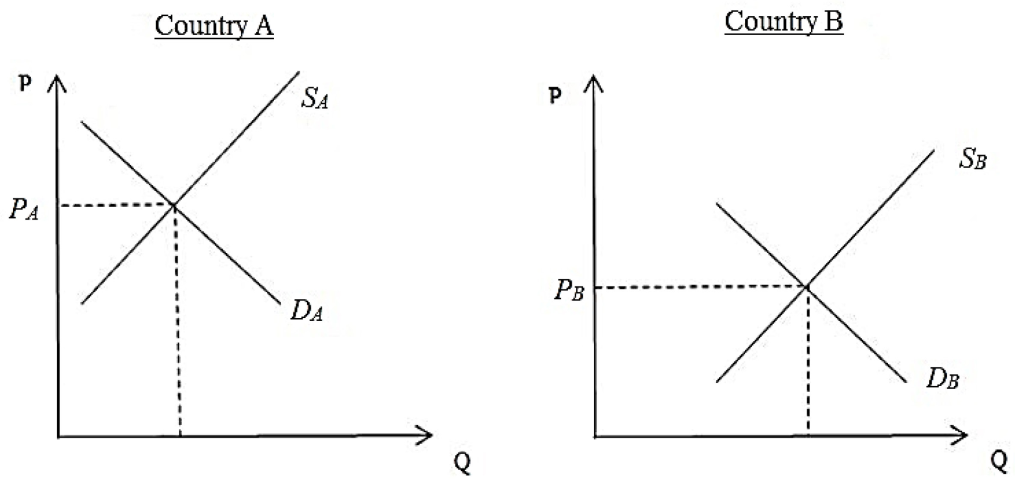
- A competitive world market,
- homogenous product,
- technology is held constant,
- economic agents are risk neutral, and
- no uncertainty.

3.4.1 Free trade between two large countries

This section will demonstrate with a PE model how the equilibrium price with free trade between two countries is determined and how each country can influence the price of the good in the other country by changing the volumes of their trade.

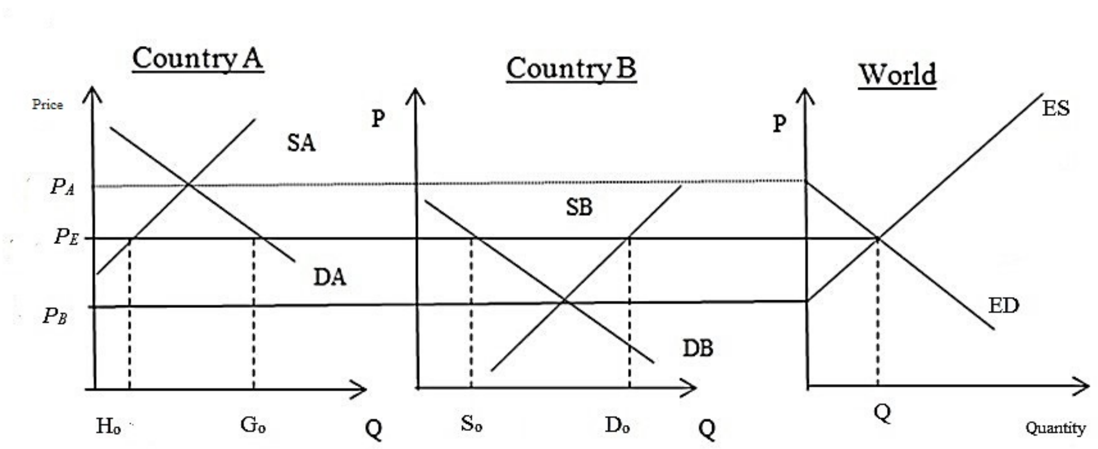
Figure 3.3 shows the equilibrium prices P_A and P_B in the domestic markets of two large countries under autarky. The equilibrium price under autarky in Country B is lower than in Country A. Hence, Country B could export goods to Country A.

Figure 3.3: Autarky equilibrium in country A and country B.



Under free trade, as shown in Figure 3.4, the price equilibrium of the two markets solves with world price P_E where B's exports (the difference in volume between B's supply of and demand for the commodity) are equal to A's imports (the difference between A's demand for and supply of the commodity). At the equilibrium price P_E, A's imports $G_o - H_o$ from B are equal to B's exports to A, $D_o - S_o$.

Figure 3.4: Joint equilibrium in Country A and B under free trade.



3.5 Trade restrictions: tariffs and non-tariff barriers

In the previous section, it was shown that free trade maximises world output and can benefit trading countries. However, practically all nations impose some restrictions to the free flow of international trade for various reasons (McLaren, 2013; Salvatore, 2005; Kenen, 2000). Restrictions include tariffs and non-tariff barriers which include import quotas and voluntary export restraints. Although there are other policy instruments that are used to restrict trade (e.g., the Agreement on the Application of Sanitary and Phytosanitary Measures[8]), these are beyond the scope of this thesis and not further described. This section focuses on the most common tariff and non-tariff barriers and the impacts of those restrictions will be outlined. The purpose of tariff and non-tariff barriers are to restrict the supply of goods to the importing country and to increase the domestic price; however, the main intention of a government imposing tariffs is to earn income as tariffs raise revenue for the government whereas non-tariff trade barriers benefit the licence holder (Salvatore, 2000; Mankiw, 2007).

3.5.1 Tariff

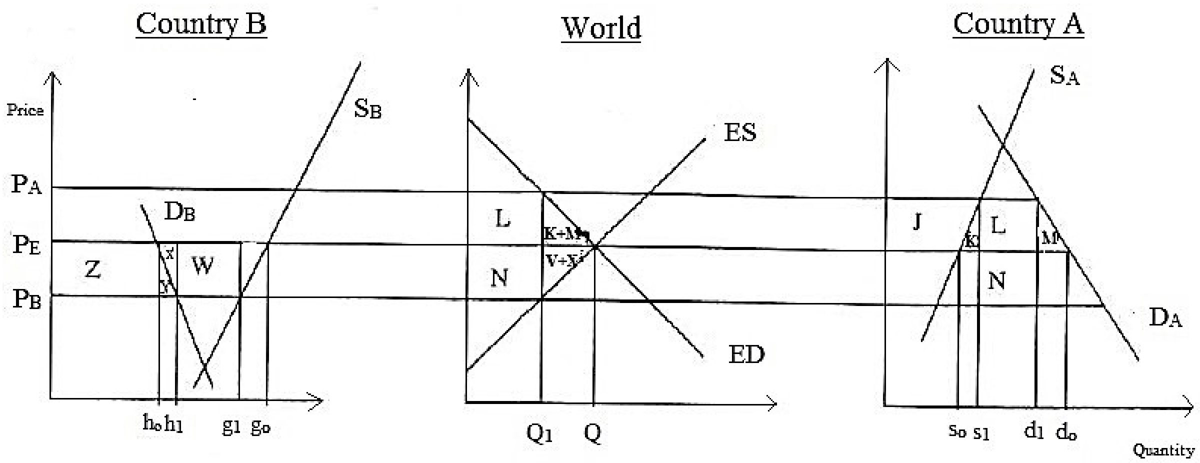
Tariffs have been widely used as a trade policy instrument (Mikic, 1998). A tariff is a tax or duty levied on the traded commodity as it crosses national borders (Salvatore, 2005). An import tariff is a tax or duty for an imported commodity levied at the point of entry into the importing country whereas an export tariff represents a tax or duty for an exported commodity (Todaro & Smith, 2009). Tariffs can be ad valorem, i.e., levied as a fixed percentage of the value of the traded commodity, or levied as a fixed sum per unit of the traded commodity, or as a combination of both (McLaren, 2013). Many factors influence the choice between the two

[8] The Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) sets out the basic rules for food safety and animal and plant health standards (WTO, 1998).

methods including: frequency of changes in the world price, reason for levying the tariff (e.g., to protect domestic industries, to reduce imports, earn revenue or a combination of these), and the general status of the economy (inflation or recession) (Salvatore, 2005).

Introducing an import tariff drives a wedge between the domestic price and the world price (Krugmann & Obstfeld, 1997; Mikic, 1998). Figure 3.5 shows the effects of a tariff where the government of Country A decided to impose an import tariff. P_E is the original free trade price, P_A is the post tariff price in the importing Country A and P_B is the post tariff price in the exporting Country B. Consequently, the effect of this tariff would cause a price increase within the importing country to P_A. This will then lead to a drop in domestic consumption from d_0 to d_1 (i.e., consumption effect of a tariff generated by the increase in commodity price) and an increase in domestic production from s_0 to s_1 (i.e., production effect of a tariff resulting of a decrease of commodity price). Hence, imports have decreased from $d_0 - s_0$ to $d_1 - s_1$. The reduction in the volume of trade in the commodity resulting from a tariff is known as the trade effect of a tariff. In the exporting Country B production decreased from g_0 to g_1 and consumption increase from h_0 to h_1. Hence, exports have been reduced from $g_0 - h_0$ to $g_1 - h_1$ (which equals $d_1 - s_1$) (Krugman & Obstfeld, 1997).

Figure 3.5: Effects of import tariffs.



Changes in producer and consumer surplus can identify the overall effect of a tariff. As shown in Figure 3.5 the gross loss of producer surplus in the exporting country is presented by area V+W+X+Y+Z, so the overall net loss is V+W. In contrast, consumers in the exporting country B have gained surplus Y+Z. Conversely, consumers in the importing country A have lost surplus J+K+L+M and producers have gained a surplus of J. However, there is also an increase in government revenue equal to L+N. Therefore, the importing country will make a welfare gain if N>K+M or a loss if N<K+M. Furthermore, effects of tariffs differ with respect to the

size of the country. Mikic (1998) stated that large country can always find a tariff that will improve its welfare as compared to free trade while for a small country there is no welfare-improving tariff.

In contrast, when a country imposes an export tariff in form of an export tax the aim is to reduce the volume of exports; it is therefore a form of export restriction. Effects differ between a large and small country. A tax on exports implemented by a large country lowers the domestic price of the taxed good, increases the world price, reduces the traded quantity and may subsequently raise national welfare. The gain depends on the ability of the country imposing the export tax to increase world prices. Thus, the welfare effect of imposing an export tax will be negative in the case of a small country. Finally, welfare in the importing country will decrease and it loses both in terms of efficiency and in terms of trade (Piermartini, 2005).

3.5.2 Import quotas

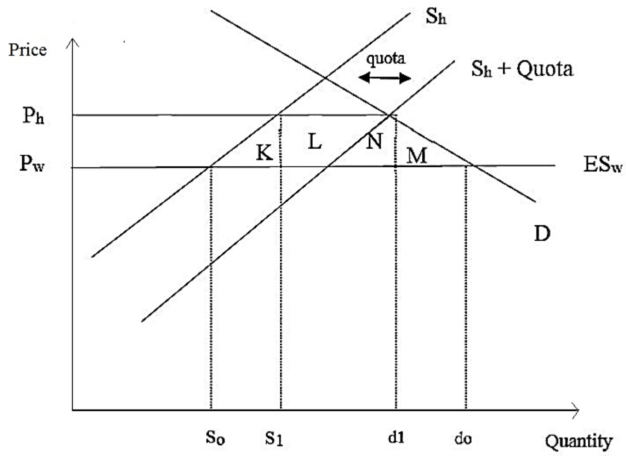
While tariffs are monetised restrictions in form of taxes imposed by governments, several types of non-tariff trade barriers have been developed to restrict trade and protect domestic industries. The most important type of non-tariff trade barriers are import quotas which restrict the quantity of a commodity allowed to be imported in a country (Todaro & Smith, 2009; Salvatore, 2005).

There are two types of import quotas. Firstly, an absolute quota which limits the imported quantity to a specific level during a certain period of time, and secondly a tariff-rate quota that allows a defined quantity of imports at a reduced tariff rate into the country during a certain time period (Salvatore, 2000). Imports above the tariff rate quota have a higher tariff rate than imports below the quota amounts. Thus, increasing the tariff rate quota leads to an increase of the amount of the good that can be imported at the lower tariff rate and thereby facilitating trade (Hawkes & Murphy, 2010).

Similar to the effects of tariffs, import quotas restrict the supply to the importing country by increasing the price of the imported good (Salvatore, 2000). This is illustrated by Figure 3.6.

As shown in Figure 3.6, under free trade, imports were d_0 to s_0 which represents the difference in domestic consumption and production. However, when the government introduces a quota on imports the difference between domestic consumption and production reduces to d_1 to s_1 as the market price increase to P_h. A major difference between the welfare consequences of a tariff and a quota is in area of L+N which would have been the revenue to the government from the equivalent tariff. If imports can be bought at price P_w on the world market but can be sold at price P_h on the domestic market, then those with the right to import (namely the license holders) will be able to make a gain of $P_h - P_w$ per unit over the volume of the quota. The profits attained by the holders of import licenses are also known as quota rents. In assessing the costs and benefits of an import quota is crucial to determine who gets the economic rents (Krugman & Obstfeld, 1997).

Figure 3.6: Effects of import quota on an importing country.



In equal measures, tariffs and import quotas reduce the quantity of imports and raise the domestic price of the commodity (Mankiw, 2007). However, as mentioned above, there is one important difference between both trade barriers that is, import quotas lead to rent. Import quotas involve the distribution of import licenses and the profits received by license holders are known as quota rents (Krugman & Obstfeld, 1997). Traditionally, the government would auction off licenses for various proportions of imports and if these are distributed free of charge license holders will gain all the rent (McLaren, 2013). This is in contrast to a tariff, where the government usually receives revenue. However, in the case of the government selling the import licenses for the maximum amount possible, part of the rent will then accrue to the government's revenue and the other part to the license holder (Mikic, 1998). As shown in Figure 3.6, if the government issued licenses for the imports free of charge, then the holders of the licenses gain the area of L+N. However, if the government sells the licenses, it receives rent and area L+N becomes revenue equivalent to a tariff if the licenses are sold for the maximum amount. Hence, the net loss from the quota will be the same as that from the equivalent tariff (areas K and M in Figure 3.6) (Mikic, 1998).

Therefore, the difference between import quotas and import tariffs is that the former may create surplus for those who hold the licenses to import while the latter increases revenue for the government. Furthermore, quotas limit the operation of markets more than tariffs and adversely affect the efficiency of a competitive price system (Anderson, 1988). While quotas tend to insulate markets, tariffs provide an explicit link between trading countries which allow the transmission of market signals. Thus, the use of tariffs instead of quotas should result in more efficient and stable world markets (Moschini, 1991). In addition, while an import quota limits the imports to a specific level with certainty, effects of an import tariff can hold uncertainty because foreign exporters may make up for all or parts of the tariff by increasing their efficiency in production or accepting lower profits. This is not possible with the quotas as the quantity of goods getting into the country is limited (Salvatore, 2000).

3.5.3 Tariff rate quota

Tariff rate quotas (TRQs), or multiple – tier tariffs, are different to an ordinary quota. Tariff rate quota is a two-tier tariff which combines the two policy instruments outlined above: quotas and tariffs. In a given period, a lower in-quota tariff is levied on imports that enter under a minimum access commitment while a higher over-quota tariff is levied on imports in excess of agreed market access (Skully, 1999). While over-quota tariffs are usually prohibited, many TRQs act as quotas generating rent for the license holders or revenue for the government. In order to obtain the desired degree of import protection, the quota element in a TRQ is combined with a specified tariff rate. Imports entering a country during a specific time period under the quantitative threshold of the quota component of a TRQ are usually subject to a lower, or sometimes even zero, tariff rate. Imports above the quota's quantitative limit are object to a much higher (usually prohibited) tariff rate (Skully, 1999).

Figure 3.7: Effects of a tariff rate quota.

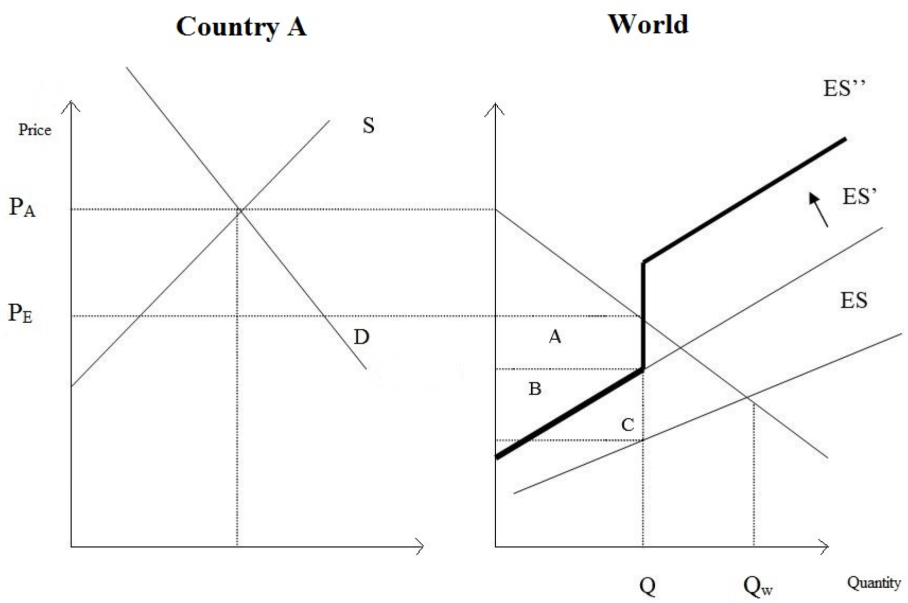


Figure 3.7 illustrates the effect of a TRQ. The domestic market of an importing country A is determined by D and S with the autarky price at P_A. This price determines the vertical intercept of the importing country's excess demand curve (ED) which describes the world market. There are three excess supply curves (ES) shown in the second graph, with ES presenting the excess supply curve if no quota tariff was applied by the importing country, ES' showing the excess supply curve including the tariff and ES'' showing the excess supply curve including the tariff and the quota. In this case, the quota rent for the license holder is equivalent to area A and area B + C is captured by the importing country's government as tariff revenue.

3.5.4 Voluntary export restraints

A voluntary export restraint (VER) is a restriction on exports set by the exporters themselves (McLaren, 2013). Usually, the reduction is accepted "voluntarily" by the exporting country due to a threat of higher trade restrictions from the importing country. When successful, VERs have equivalent economic effects like import quotas. The only difference is that they are being administered by the exporting country, and hence the exporting country obtains the economic rent (Salvatore, 2005; Mikic, 1998). An example of this is provided by the VERs for higher prices on quantities of New Zealand butter and cheese to the United Kingdom where New Zealand has received preferential treatment to export limited quantities of both commodities. Thus, New Zealand earned economic rent from those export, presented as the differences what normally would be earned at the world market price and the higher price from the VER (Amor & Saunders, 1999).

3.6 Trade and the environment

The previous sections provided a summary of the theory of trade and outlined some common tariff and non-tariff trade restrictions and their impacts on a country using a partial equilibrium approach. In this section, the relationship between trade and the environment will be briefly described because in some cases the assumptions of markets do not hold and markets fail. The section finishes with an outline of the theory of GHG emissions.

One condition underlying the workings of a market is that they assume perfect competition. In order to have perfect competition, several requirements need to be met. This is that numerous firms offer an identical good on the market with many buyers available for these products; there is perfect information on the market and no external costs occur. Finally, property rights are clearly defined in a perfectly competitive market. If any of these conditions is not met, then the analysis of a market with perfect competition may not apply and the market may fail due to imperfectly defined property rights, imperfect information, external costs and only small numbers of buyers and seller, with restrictions to enter and exit the market (Randall, 1987).

Market failure may occur through environmental pollution or GHG emissions. In the context of climate change, GHG emissions are negative externalities[9] generated by production and consumption of certain products which represent a cost that is not transmitted through market prices. For example, producers of livestock do not pay for the costs of GHG that are emitted during the production of their product (Wreford, 2006).

3.6.1 Theory of agricultural GHG emissions

Agricultural GHG emissions are predominantly generated by two sources, animal numbers and the use of nitrogen; and methane (CH_4) and nitrous oxide (N_2O) are the two main GHG generated by agricultural production. Methane emissions from livestock are predominantly generated through digestion ("enteric fermentation") and ruminant fecal waste decomposition ("manure management") (IPCC, 2007). The amount of CH_4 emissions is determined by type and quality of animal feed and the amount of feed intake (Lassey, Lowe, Manning & Waghorn, 1992).

[9] An externality is a by-product of a consumption or a production that is not valued by the market.

While N_2O is emitted in lower quantities than CH_4, it has a significant effect on agricultural GHG emissions due to its high global warming potential (GWP)[10]. Nitrous oxide is generated from several sources within the agricultural production process. Firstly, N_2O is emitted through animal waste management systems (Cagatay et al., 2003). The IPCC (1996) identified six alternative systems for animal manure treatment: this is anaerobic lagoon, liquid systems, daily spread, solid storage and drylot, pasture range and paddock, used fuel, other system. Secondly, N_2O is directly emitted from agricultural soils resultant from synthetic fertiliser application, the use of animal waste as fertiliser, nitrogen-fixing crops, and crop residues. Thirdly, N_2O is emitted from animal production through direct soil emissions which refers to manure on grassland from grazing livestock and left there for decomposition. Fourthly, N_2O indirectly emitted by nitrogen used in agriculture which are generated from atmospheric decomposition of ammonia and nitrogen oxides, and leaching (IPCC, 1996).

In order to determine CH_4 and N_2O emissions for a country or for the supply of the meat and dairy sector, livestock numbers are used, among others (Cagatay et al., 2003). A guideline for the calculation of coefficients for CH_4 and N_2O emissions from livestock was developed by the IPCC methodology for greenhouse gas inventories (1996). Default emission factors were produced by the IPCC for the calculation of coefficients for different sources of gases, for different countries. Recently FAOSTAT (2013) also determined emissions factors for several countries. Mostly, the CH_4 and N_2O emissions from these sources are converted to their CO_2 equivalents by multiplying with their respective weights (21 and 310) to give CO_2 equivalents (IPCC, 1996). Hence, GHG emissions from livestock differ between countries and these values will vary considerably within each region. Therefore, New Zealand, as have many other countries, has conducted further research to produce more accurate emission factors (Wreford, 2006; Cagatay et al., 2003).

Groundwater nitrate contamination

Another main issue with the potential to cause environmental degradation from agricultural production is groundwater nitrate contamination due to the use of nitrogen fertiliser. Although this issue is not directly part of this study, it has a significant impact and is therefore briefly described.

In particular, dairy production has been identified to cause high nitrate concentrations in groundwater, both directly, through the application of nitrogen fertiliser on grassland and

[10] GWP is a CO_2-weighting. It is a relative measure of how much heat a greenhouse gas traps in the atmosphere and is expressed as a factor of CO_2.

indirectly, through the nitrogen content of grass and other feeds deposited in urine and manure (Rae, 1999). Bidwell (1999) developed an environmental damage function of how the environmental impact of dairy production can be measured as shown in Equation 3.1. He demonstrated that nitrogen fertiliser (Na/ha) and the amount of concentrated feed grain (ka) used in each region (shown for region a in Equation 3.1) both contribute to nitrate emissions with some of their nitrogen content removed in milk (qsa). Whitehead (1995) defined the impact of emissions on groundwater concentrations (GNCa) dependant on the degree of dilution through annual drainage (see Equation 3.1).

$$GNCa = \frac{(x0 + x1\ Na + x2\ ka - x3\ qsa)}{W} \qquad (3.1)$$

GNCa: average groundwater nitrate concentration in region a ($g/m^3/yr$)
Na: nitrogen use in region a (kg/ha/yr)
ka: feed grain (concentrate) use in region a (kg/ha/yr)
qsa: quantity of raw milk produced in region a (l/ha/yr)
W: annual average drainage per year (mm)

3.7 Chapter summary

This chapter examined the development of the absolute and comparative advantage trade theories, described gains from trade using Ricardo's trade models and outlined countries' incentives to engage in trade. The partial equilibrium model was used to illustrate the impacts of common trade restrictions such as tariff and non-tariff barriers. Furthermore, the relationship between trade and the environment was explored. The chapter finished with a brief description of the theory of GHG emissions.

The next step in this study selects a suitable trade modelling approach to analyse the impacts of increased meat and dairy consumption and production as well as different trade policies in India and China on consumption, production, trade and GHG emissions, particularly in New Zealand.

Chapter 4
Trade models literature review and model selection

4.1 Introduction

Trade modelling approaches have been widely adopted in the modelling of global changes in consumption and production patterns and trade policies. There are two analytical frameworks, the partial equilibrium (PE) approach and the general equilibrium (GE) approach. One of the main objectives of trade modelling is to determine the equilibrium prices and quantities on set(s) of market(s) which are subject to various policy changes (Tongeren, 2005). Both models can be static or dynamic, short, medium or long-term and can be single or multi-country (Tongeren, Meijl & Surry, 2001).

The models are different through the way in which parameters are selected, assumptions made and the interrelationships presented. GE models examine inter-industry linkages for all commodities simultaneously in all sectors and countries by using an input-output structure. They provide the solution for income-expenditure equilibrium in the economy by considering the interactions with factor markets. In contrast, PE models are often more sector specific. They assess particular industry sectors (e.g., agriculture) or commodities by capturing demand and supply interrelationships among different commodities of the specific sector. PE models ignore the interrelationships with other sectors and/or the total economy, and they usually do not take into account the link between factor incomes and expenditure (Cagatay & Saunders, 2003; Tongeren et al., 2001; Piermartini & Teh, 2005). PE models have been predominantly used to assess the agricultural sector in an economy. Furthermore, trade models have also been used to assess other global issues such as environmental ones (e.g., Burniaux & Truong, 2002; Woltjer, 2011; Saunders, Wreford & Cagatay 2006; Saunders, Kaye-Blake & Turner, 2009; Burniaux & Chateau, 2010; Zhai, Lin & Byambadorj, 2009; Eboli, Parrado & Rosen, 2009).

This chapter examines the two analytical frameworks, the PE model and the GE model approaches, and reviews their use in studies that examined changes in food consumption, production and trade policies in China and India and their impacts on consumption, agricultural production and trade in other countries. This is followed by a review of different techniques and studies that analysed environmental impacts, especially from GHG emissions, from changing consumption, production and trade patterns. The chapter finishes with the selection of the model that fits the purpose of this study.

4.2 Partial equilibrium (PE) trade models

PE trade models examine interactions within only one or a few industry sectors (e.g., agriculture) of the economy and assume that the impacts on the rest of the economy are exogenous, non-existent or small (Piermartini & Teh, 2005). There are a wide range of PE trade models ranging from specified single-sector single-country models through to multi-market models and multi-regional multi-commodities models. Multi-commodities models capture the demand and supply interrelationships among different commodities. These are specified as functions of prices and income in either linear or log linear behavioural equations. The PE framework can further incorporate exogenous variables such as technical change, population growth and household income but also feedbacks into other sectors (e.g., energy) impacted can be included exogenously (Piermartini & Teh, 2005; Tongeren et al., 2001).

A purpose of agricultural PE models is to provide detailed insights into the implications for national and international agricultural markets of existing and alternative agricultural policies. In particular, the models provide information on the effects of such polices on domestic supply, demand, trade volumes and global and domestic market prices (see Section 3.4). This information can be used to determine the welfare effects for consumers and producers and to analyse the impact on aggregate net imports or exports (see Section 3.5.1) (Tongeren et al., 2001; Blandford, 1990). However, more complex models can provide for both exports and imports of similar products and allocate these trade flows between regions to allow for differentiated markets and bilateral trade flows (Roningen, 1997). For this, there are two approaches (Cagatay & Saunders, 2003). In the pooled approach (non-spatial approach), the global market represents a pool to which each country supplies and others demand from, without further specification of bilateral relationships. In this approach, supply and demand for a good is aggregated into one figure and then equilibrated on a market-wide basis. In the bilateral approach, interactions between each buyer and seller for each commodity on the global market is explicitly represented, and trade flows between specific regions can be identified (Cagatay & Saunders, 2003).

The information that agricultural PE models can provide differ according to country coverage, commodity coverage and temporal properties. This is largely determined by the model structure and the way agricultural policies are incorporated in the model (Blandford, 1990).

PE models can treat commodities as either homogenous or heterogeneous. Commodities are called homogenous when the goods of one producer perfectly substitute for those of another. Each actor in the market is either a buyer or a seller of the goods, but never both. In contrast, heterogeneous commodities are goods that are imperfect substitutes, thus there is product differentiation on the market. Each actor in the market may be both a buyer and a seller at the same time. The Armington (1969) method is one way to introduce product differentiation by assuming that products are differentiated by country of origin (Armington, 1969; Tongeren et al., 2001; Cagatay & Saunders, 2003).

Another important characteristic concerns the temporal property of PE models. In general, a model can be either dynamic or (comparative) static. Static models compare the new equilibrium state to the base equilibrium state after all changes have occurred and markets have cleared (Roningen, 1997). In contrast, dynamic models can be used to follow the accumulation of stock variables through time. Hence, they are more complex and resource intensive to run than static models (Roningen, 1997). A widely used approach to incorporate dynamic features into equilibrium models is to specify a recursive sequence of temporary equilibria for each time period. In each time period, the model is solved for an equilibrium based on the exogenous conditions predominating in that particular period. In between periods, stock variables are updated as a result of the equilibrium outcomes of the previous period (Roningen, 1997). Examples of recursive dynamic PE models are AGLINK of OECD, FAO World Model, FAPRI, GAPsi and LTEM (Tongeren et al., 2001; Cagatay & Saunders, 2003).

In PE models, key parameters include own- and cross-price elasticities of demand and supply systems, income elasticities of demand, substitution elasticities in supply systems, Armington (substitution) elasticities in import demand, among others. (Tongeren et al., 2001). There are two main approaches to estimating parameters in behavioural equations. Parameters can be econometrically estimated, typically by single-equation specifications, using either time series or cross-sectional data (Huang, Jun, Xu, Rozelle & Li, 2007). This can be a reasonably complex method to apply and is often not feasible due to lack of data. Parameters can also be incorporated into a model using a synthetic approach where initial estimates of parameters (e.g., elasticities) are obtained from secondary sources and other parameters in the given functional forms are calibrated to the initial equilibrium dataset (Tongeren et al., 2001).

Advantages of the PE approach include the level of commodity disaggregation, ease of traceability of interactions, transparency of results, relatively small model size and the relatively small number of behavioural variables. In addition, by concentrating on a limited set of factors such as a few prices and policy variables, PE modelling allows for a relatively fast and transparent analysis of a wide range of policy issues (Francois & Hall, 1997). These are the main features that draw many researchers to use PE frameworks for assessing the effects of agricultural and trade policy changes (Francois & Hall, 1997; Roningen, 1997). However, it is often argued that PE models do not give a complete representation of the economy as they show only part of the economy and assume that the impact of that sector on the rest of the economy and vice versa are either non-existent or very small (Piermartini & Teh, 2005). However, as long as limitations are kept in mind, useful insights can be provided under time and data constraints that hinder more complex forms of analysis (Francois & Reinert, 1997). Also, PE modelling can be a useful analytical tool for environmental issues as they are often associated with specific production processes or products (Tongeren et al., 2001).

Since the 1990s, there has been an increasing interest in agricultural focused PE trade models by international institutions and organisation due to shifts in applied policies towards a more liberal agricultural industry (Cagatay & Saunders, 2003; Tongeren et al., 2001). The most widely used multi-country, multi-commodity PE trade models are FAO commodity model of FAO (FAO, 2003), AGLINK and MTM of OECD, ESIM and SWOPSIM of USDA/ERS (Tangerman & Josling, 1994; Roningen & Dixit, 1990), GLS model of Tyers and Anderson (1986), IMPACT of IFPRI (Rosegrant, 2012), FAPRI model of the Food and Agricultural Policy Research Institute (FAPRI, 2004) and GAPsi (Frenz & Manegold, 1988).

4.3 General equilibrium (GE) trade models

GE trade models are economy-wide models that analyse interactions across industries within a sector as well as across sectors of an economy. In a standard GE model, inter-industry linkages are captured by an input–output structure within each regional economy, and it provides the solution for income-expenditure equilibrium in the economy by considering the interactions with factor markets (Piermartini & Teh, 2005). GE models can incorporate technical changes, population growth and income as endogenous factors. GE models include equations that describe behavioural parameters of producers, consumers, importers, exporters and possibly other agents in the economy (Piermartini & Teh, 2005; Tongeren, 2005). In GE models, the parameters are the outcomes of mathematical procedures which indicate each year's behaviour (Cagatay & Saunders, 2003). Moreover, in the GE framework the opportunity costs of factor movements between the sectors, the impacts of changing factor returns on the demand side and the cost to the economy of agricultural support and subsidy policies are computed (Hertel, 1990). In a standard GE model, perfect mobility of capital and labour between sectors in a country is assumed (Verburg, Stehfest, Woltjer & Eickhout, 2009). Furthermore, product differentiation can be introduced to the GE framework using the Armington (1969) approach (see Section 4.2) or by using the differences in fixed costs (e.g., R&D, marketing costs) on the supply side (Cagatay & Saunders, 2003).

Compared to PE models, an advantage of GE models is that they typically capture implications for international trade for the whole economy. This is achieved by covering the circular flow of income and expenditure and taking into account inter-industry relationships. Hence, GE models give a more complete representation of a country's economy than PE models. However, in order to achieve this, GE models require more simplifications and assumptions than PE models, and there is also difficulty in adjusting data, and the required time-series data is often not available (Tongeren et al., 2001).

A widely used GE model for economy-wide global market analysis is the GTAP model (Hertel, 1997). The current database version is GTAP 8 released in 2012. It divides the world into 113 countries/country groups each divided into 57 sectors including 20 for agriculture, food, beverages and tobacco. An input-output structure (based on input-output tables of countries/country groups) defines the standard model which explicitly connects sectors in a value added chain from primary goods over intermediate processing to the final assembling of goods and services for consumption (Narayanan, Hertel & Walmsley, 2012. Other important GE trade models are: GREEN-OECD (Lee, Oliviera-Martins & Mensbrugghe, 1994), RUNS-OECD, MEGABARE and GTEM, ABARE (Pant, 2007), the WTO Housemodel (Tongeren et al., 2001), and the global CGE model for heterogeneous firms (Zhai, 2008; Petri, Plummer & Zhai, 2011).

In summary, there is no ideal model that suits all purposes. Both GE models and PE models have advantages and disadvantages given the objectives addressed by the study and the issues or policy changes assessed (Tongeren et al., 2001; Tongeren & Meijl, 1999). While GE models examine supply and demand for all commodities simultaneously in all sectors and countries and consider the interactions with factor markets, PE models assume interactions within only one or a few industry sectors of the economy and ignore interactions with the rest of the economy. However, this allows for a more transparent and detailed analysis of the specific sector. In addition, a higher level of commodity disaggregation is possible in PE models while GE models usually work on more aggregate level. When it comes to analysing agricultural policies, as undertaken in this research, usually more detail is required, particularly in terms of commodity disaggregation.

4.4 Literature Review

This section reviews empirical studies using PE and GE approaches to assess effects of changes in consumption and production patters and/or changes in trade policies in China and India on food consumption, agricultural production and international trade. This is followed by a review of studies and techniques analysing effects of changing consumption patterns on trade and the environment, particularly on GHG emissions.

4.4.1 Literature on trade modelling

Many studies have employed PE and GE models to analyse consumption and production growth as well as different trade policies in China and India and how they affect global food demand, supply and international trade (e.g., Delgado, Rosegrant, Steinfeld, Ehui & Courbois, 1999; Rosegrant et al., 2001; Anderson & Strutt, 2012a; 2012b). Another important method to assess these changes is the analysis of Total Factor Productivity (TFP) (see also Section 2.3.2) which can be used to support and inform trade modelling. TFP is a measure of output per unit input. Modelling TFP growth in agriculture production measures both technological innovation and changes in efficiency for different agricultural commodities in production frontier functions (Nin et al., 2004; Ludena et al., 2007; Rae et al., 2006; Rae & Hertel, 2000). In this section, relevant studies using trade modelling are reviewed. Additionally, this section reviews some studies that have applied TFP growth analyses, particularly in China.

The International Food Policy Research Institute (IFPRI) has developed the IMPACT model (International Model for Policy Analysis of Agricultural Commodities and Trade) which has been used in several studies to model China's and India's future food demand, supply and trade. The IMPACT model is global agricultural PE model. It includes a large set of country and regional sub-models. For each country/region, supply, demand and prices for agricultural commodities are determined. Country and regional agricultural sub-models are linked to the rest of the world through trade. Supply and demand functions incorporate elasticities to estimate the underlying production and demand. World agricultural commodity prices are determined annually at levels that clear international markets (Rosegrant & the IMPACT Development Team, 2012). In their study, Delgado et al. (1999) used the IMPACT model to analyse global livestock product consumption and production by 2020. Projections showed that China's meat consumption was expected to almost double while its milk consumption was projected to grow by 76 per cent by 2020. Similarly, India and other South Asian countries were predicted to have a large increase in total milk consumption by 2020. India's milk consumption was projected to grow by 116 per cent while meat consumption was expected to grow by 78 per cent by 2020.

With regards to production, it was shown that for both countries the projected increase in meat and milk consumption was greater than the projected growth in production (Delgado et al., 1999).

The IMPACT model was also used by Rosegrant et al. (2001) to assess the effects of global dietary changes and changes in trade policies in several countries. In an alternative scenario, the researchers modelled the tripling of India's meat demand from 9.4 million tonnes to 22.7 million tonnes by 2020. Additionally, India's income elasticities of demand, feed ratios and growth rates for livestock production were increased. Results showed that the increase in India's meat demand would have to be met both by increased domestic production and by expanded imports of meat. For example, Indian meat imports were projected to rise to 1.8 million tonnes by 2020 (compared with 0.2 million tonnes in the baseline). Rosegrant et al. (2001) also found the demand for cereal for livestock feed would put additional pressure on both domestic cereal production and cereal imports. However, their projections showed only a small effect on global cereal and meat prices. Under this scenario, beef prices in international markets were projected to decline only by 2 per cent by 2020 (compared with 4 per cent in the baseline scenario) and wheat prices were projected to drop by 3 per cent (compared with 8 per cent in the baseline scenario). The researchers argued that international food markets would be resilient enough to absorb India's increasing demands (Rosegrant et al., 2001).

Huang, Rozelle and Rosegrant (1999) used a PE model of China's food demand, supply and trade to make projections by 2020. The major components of the model were a supply model for the wheat, maize, rice, other grain and cash-cropping sectors while demand models were specified separately for urban and rural consumers for wheat, rice, other grain and six animal products. World price projections were generated by IMPACT by IFPRI, the PE trade model outlined above. Similar to the study results from Delgado et al. (1999), Huang et al. (1999) projected a doubling of China's per capita demand for red meat by 2020. Per capita growth levels for poultry and fish were higher than for meat, albeit starting from a lower level. The projected rise in meat, poultry, fish, and other animal product demand was projected to stimulate demand in feed grain which was projected to increase to 240 million tonnes by 2020 in the baseline scenario. This growth rate showed that feed grain as a proportion of total grain utilisation is projected to move from 23 per cent in 1994 to 40 per cent in 2020 (Huang et al., 1999).

A number of studies were conducted when China accessed the WTO in 2001 focussing on impacts for China's food demand and supply and global trade patterns from these trade reforms. For example, Huang et al., (2007) examined the impacts of trade liberalisation on China's agriculture and poverty level using the PE model CAPSiM (Chinese Agricultural Policy's Agricultural Policy Simulation and Projection Model). The model was particularly developed for the analysis of agricultural policies affecting agricultural production, consumption, commodity prices and trade in China. Most of the elasticities have been estimated econometrically, and particularly the change of these over time because income and food budget also change over time. The study found that under full agricultural trade liberalisation the aggregated price for food was projected to rise by 5 per cent while crop prices were expected decline by about 2 to 4 per cent. Further, for the average farmer, agricultural output was projected to increase by 6 per cent under trade liberalisation. Thus, Huang et al. (2007) concluded that overall the net impact from full trade liberalisation would be positive for the average farm household in China.

In their study, Wang, Parton and Deblitz (2008) used a PE beef model to analyse increased beef demand in China under different scenarios. In their model the beef market was comprised of the Chinese domestic market and the international market. The beef price was set endogenously while other variables were treated as exogenously. The model was based on the assumptions that beef was homogenous and that the elasticities of supply, demand and net export demand were constant. Other constant variables of the models were income and population growth. The study found that China could meet the increased beef demand by growth in domestic beef production (Wang et al., 2008).

Rasin (2006) examined the impacts of international full trade liberalisation and its effects on meat and dairy consumption, production and trade for several countries, particularly for New Zealand. The study used the Lincoln Trade and Environment Model (LTEM) which is a PE model focussing on the agricultural sector (Cagatay et al., 2003). Model results suggested that with full international trade liberalisation, New Zealand prices for sheep meat, beef and dairy commodities were predicted to increase by 2013, consequently meat and dairy production was predicted to increase and accordingly, producer returns were predicted to increase from between 14 per cent for beef to 37 per cent for dairy commodities by 2013. Similarly, net trade from New Zealand was predicted to grow with increased exports expected across all meat and dairy commodities (Rasin, 2006).

Many studies used GE models to project future growth in food demand, supply and trade flows in China and other Asian countries (including India) with the majority using the standard or a modified version of GTAP (e.g., Rae & Hertel, 2000; Nin et al., 2004). In a recent study, Anderson & Strutt (2012a) used the standard GTAP model to examine how economic growth and associated changes in China and India alter agricultural markets in other countries/regions.

They developed a model of the world economy that compared baseline projections with alternative growth strategies and trade policy scenarios by 2030. In their baseline of 2004, Anderson & Strutt (2012a) assumed agricultural land and trade policies of each country not to change between 2004 and 2030 while national real GDP, population, unskilled and skilled labour, capital; and other natural resources (oil, gas, coal, and other minerals) were assumed to grow at exogenously set rates in the same period. The model included 33 countries/country groups and 26 sectors/commodities. Model results indicated that the share of global exports of all commodities from Asian developing countries (including China and India) was expected to double by 2030. China's shares of global agricultural and processed foods exports were projected to decrease while India's were projected to increase significantly by 2030 while India's share of global agricultural and food imports was expected to remain the same (Anderson & Strutt, 2012a). Results further showed that between 2004 and 2030 China's real per capita food consumption was expected to more than triple, and India's real per capita food consumption was expected to more than double. It was also shown that China's grain consumption was projected to more than double and fuel consumption more than triple while India's grain consumption was estimated to slightly decrease while fuel consumption was projected to almost triple by 2030. Overall, the projections showed that by 2030 Asia was expected to consume half the world's grain and nearly half the world's fossil fuels (Anderson & Strutt, 2012a).

In a similar study, Anderson & Strutt (2011; 2012b) examined changes in trade patterns for high-income countries of the 'North' (i.e., Europe, North America, Australia and New Zealand, and Japan) and developing countries of the 'South' in the course of continuing economic growth and structural changes in Asia. Using the GTAP model, the researchers projected a baseline scenario for the world economy from 2004 by 2030 and compared it with alternative scenarios such as slower economic growth in the North and trade liberalisation in Asia. Study results suggested that the share of South-South trade in global trade was expected to grow from 13 to 27 per cent by 2030 in the baseline or even higher (up to 29 per cent) when there was slower economic growth in the North or trade liberalisation within Asia. In contrast, the extent of North-North trade as a share of global trade was projected to decrease from 51 to 30 per cent in the baseline projections by 2030 (Anderson & Strutt, 2011; 2012b).

As mentioned above, total factor productivity (TFP) is a measure of output per unit input. Analyses of TFP growth is often used to support and inform trade modelling. Rae et al. (2006) examined TFP growth for several sub-sectors of China's livestock sector between 1990 and 2000 using panel data. Results showed that between 1990 and 2000 milk production had the highest predicted growth rates for technical change but the lowest growth in TFP. In contrast, TFP in the beef sector was higher. It was estimated to grow by 2.2 per cent annually between 1990 and 2000. This was composed of a 3.9 per cent annual growth in technical change but a decrease of 1.7 per cent per year in technical efficiency (Rae et al., 2006).

Ludena et al. (2007) projected global TFP growth rates for agriculture, including crops, ruminants and non-ruminant livestock for eight world regions by 2040. For each sector, the average change in TFP as well as the change in efficiency and technical change were estimated for two periods: 1961–1980 and 1981–2000, and were then projected out to 2040. Results showed that in most regions productivity gains in livestock production were greater than those in crop production. Results further suggested for a convergence of non-ruminant and crop productivity in developing countries to productivity levels of developed countries. China's agricultural TFP growth rate was projected to grow at a rapid rate by 2040. Projections showed that TFP growth for ruminants' production in China was estimated at 3 per cent annually while TFP growth for non-ruminant livestock was projected at almost 7 per cent annually. China's projected TFP growth for non-ruminants was predicted to account for 70 per cent of the global average TFP growth in this sector. In South Asia (including India), projected annual TFP growth rates for ruminants and non-ruminants were 2 per cent and 3 per cent, respectively (Ludena et al., 2007).

To summarise, several empirical studies used PE and GE models to project China and India's growth and changes in food consumption and production as well as their impacts on other countries' consumption, production and trade patterns. Modelling results from these studies predicted varying growth rates for consumption and production of meat and dairy commodities in India and China. However, only a few studies exist that specifically focus on the impacts for New Zealand's agricultural production, consumption and trade patterns from these changes. In addition, many of the reviewed studies investigated the impact of new trade policies, particularly after the Uruguay and Doha Round, on consumption, agricultural production and international trade of agricultural commodities in other countries. These studies suggested that trade flows would increase under free trade, particularly from Asia. Again, not many of those studies concentrated on the impacts for New Zealand.

4.4.2 Literature analysing effects of changing dietary patterns and trade policies on trade and the environment, including GHG emissions

A number of methods exist to analyse the impacts of changing consumption and production patterns on trade and the environment and in particular on agricultural GHG emissions. Integrated Assessment Models (IAM) are characterised by combining multidisciplinary approaches into a single framework to evaluate climate change impacts. They incorporate for example relationships between climate change and economic effects (e.g., Stehfest et al., 2009; Kemfert, 2002). In recent years, multi-regional input-output models have been extended to cover global economies and concentrate on impacts on GHG emissions, and thus have led to several assessments of GHG emissions incorporated in trade (e.g., Hertwich & Peters, 2009; Peters & Hertwich, 2008; Wiedmann, Wilting, Lenzen, Lutter & Palm, 2008). Also, several GE and PE trade models have been extended into the area of environmental modelling incorporating environmental sub-models. Some examples are LEITAP, GTAP-E, LTEM and OECD- ENV linkages models (e.g., Burniaux & Truong, 2002; Woltjer, 2011; Saunders et al., 2006; 2009; Burniaux & Chateau, 2010; Zhai et al., 2009; Eboli et al., 2009, Rae & Strutt, 2001).

This section reviews studies that examined the impacts of changing dietary patterns on trade and the environment, and in particular on GHG emissions, using different methods. Ideally, this review would concentrate upon the countries of key interest to this research (namely China, India and New Zealand); however, due to the small number of studies focussing on these countries, studies of other countries have also been included in this review.

The Integrated Model to Assess the Global Environment (IMAGE) was used by Stehfest, Bouwman, van Vuuren, den Elzen, Eickhout and Kabat (2009) to assess the impacts of different dietary variants (varying from less meat consumption to no intake of animal products) and its consequences for GHG emissions, land use and the carbon cycle. The global environmental model explored the long-term dynamics of global change as a function of drivers such as economic and demographic development and changes in the energy and agricultural system. The model consists of several sub-modules that feed into the central model including a climate policy model used to calculate global emission pathways that lead to a stabilisation of the atmospheric GHG concentration, an energy system describing the long-term dynamics of the production and consumption of nine primary energy carriers for five end-use sectors in 26 world regions, and an agricultural model provided data on land use for crops and livestock production systems. The study found that GHG emissions differ substantially between different dietary patterns. Results showed that a global food transition to less meat, or even a complete switch to plant-based protein food is projected to have a substantial effect on GHG emissions, particularly methane (CH_4) and nitrous oxide (N_2O) emissions would be reduced substantially. This study gives insights into the impacts of different consumption patterns on GHG emissions and other environmental parameters, however it did not assess the economic consequences of different dietary patterns (Stehfest et al., 2009).

Erickson, Owen and Dawkins (2012) examined the potential economic effects of environmentally friendly consumption behaviour that may reduce GHG emissions in the UK. This included diet shifts towards less meat and dairy consumption as well as the reduction of purchases of clothing and other household items. In order to model the trade-related impacts of low carbon consumption behaviour, they used an environmentally extended input-output model. The global multi-regional input-output (MRIO) model allowed for the identification of countries (and sectors) in which trade impacts could occur. Results of the study showed that the UK economy would benefit from increased consumer spending on products produced domestically while there would be a negative economic impact on low income countries due to drops in production (Erickson et al., 2012).

Several GE and PE trade models have been extended for the area of environmental modelling incorporating environmental sub-models. In his study, Woltjer (2011) used the GE model LEITAP to analyse the effects of changes in meat and dairy production and consumption in the European Union (EU27) on global agricultural production, energy demand and land use. The LEITAP model is a multi-regional, static, applied GE model (Hertel, 1997). It is based on the GTAP database but has been extended to allow projections of effects of reduced meat consumption and production on agricultural production, energy demand and land use. Results showed that a reduction in meat consumption in the 27 countries of the European Union was projected to decrease livestock production in the area significantly. This reduction was then projected to affect global demand for animal feed which was projected to drop by 6 per cent by 2020. Additionally, modelling projections showed a significant increase in global fossil energy demand from the purchase of other commodities that are higher in fossil energy use than the production of meat products. While this study showed impacts of changing dietary patterns on agricultural production, land use and energy demand, it did not measure impacts on GHG emissions directly but gave indications on how meat consumption could impact global energy demand (Woltjer, 2011).

Evaluating the environmental consequences of increased and more liberalised agricultural trade, Schmitz, Biewald, Lotze-Campen, Popp, Dietrich, Bodirsky, Krause and Weindl (2012) used the spatial economic land use model MAgPIE (Model of Agricultural Production and its

Impact on the Environment). The researchers undertook spatial mapping of land use patterns and GHG emissions. MAgPIE is a recursive dynamic optimisation model in which the demand side is represented by 10 world regions including 16 cropping and 5 livestock activities. These livestock activities are related to specific feed energy requirements per animal product and per region. Differences in the livestock systems cause different emission levels from livestock. GHG emissions of CO_2, CH_4 and N_2O were calculated based on land use changes and agricultural activities. Biophysical inputs were derived from a dynamic global vegetation model. Study results showed that under full international trade liberalisation by 2045, China was expected to export more livestock products while North America and Europe were projected to export less agricultural commodities. China's domestic demand for livestock products was projected to increase significantly, and thus was still expected to dominate the export market for meat products under liberalised trade. With regards to GHG emissions, results indicated that most GHG emissions were to occur in Asian regions, especially in North-East China and North India. Schmitz et al. (2012) concluded that further international trade liberalisation could lead to higher economic benefits for China but could negatively impact the environment by increasing GHG emissions from increased livestock production, if no other regulations are put in place (Schmitz et al., 2012).

A similar study was conducted by Verburg et al. (2009) that used the coupled LEITAP-IMAGE model to analyse the impacts of different trade patterns on agricultural consumption, production, trade and GHG emissions for different world regions between 2001 and 2050. They used the modelling framework of the global GE trade model LEITAP and the global environmental model IMAGE. As mentioned above (see Woltjer, 2011), the LEITAP model is a multi-regional, static, applied GE model based on an extended version of GTAP (Hertel, 1997). Demand, production and trade of agricultural commodities were calculated by the LEITAP model while the IMAGE model provided the environmental parameters of land use change, land use for livestock systems and GHG emissions. Results showed that under full international trade liberalisation the global production of dairy and beef were not expected to change much, however production was projected to shift from North America and Europe to South America and Southeast Asia. Results further indicated that international trade liberalisation was expected to significantly increase global GHG emissions from agriculture (Verburg et al., 2009).

PE models have also been extended to assess changing consumption, production and trade patterns and its impacts on international trade and the environment. Saunders et al. (2006) used the Lincoln Trade and Environment Model (LTEM) to examine the impacts of agricultural trade liberalisation of dairy products on GHG emissions, focussing particularly on the effects for New Zealand. The LTEM is a PE model based upon VORSIM (Roningen, 1986; Roningen et al., 1991; Roningen, 2012) focussing on the agricultural sector. The model has been extended to allow the link through supply to production systems and their physical and environmental impacts. Changes in GHG emissions produced by several agricultural sectors can be projected with the model. Hence, this model allows for both, the simulation of agricultural policies as well as mitigation and other policies, applied either as physical or financial criteria. In their study, Saunders et al. (2006) found that GHG emissions in New Zealand were projected to increase significantly from freer trade of dairy commodities. The same PE model was used in a more recent study by Saunders and Saunders (2011) to assess the impacts of the New Zealand Emissions Trading Scheme (ETS) (and similar programs in other developed nations) on prices, production and trade from New Zealand's agricultural sector as well as changes in GHG emissions from livestock. The ETS was created as the primary response to New Zealand's obligations to lower emissions under the Kyoto Protocol, it puts a price on GHG emissions to provide an incentive to reduce emissions. In contrast to Saunders et al. (2006) where the impacts of various agricultural policies were modelled, in this study the LTEM was used to simulate different mitigation policies. Results showed that at the industry level the ETS alone was projected to have both a minimum effect on GHG emissions and production in agriculture. However, the researchers pointed out that if the scheme would be employed in conjunction with mitigation technologies, this would reduce emissions by almost 20 per cent by 2020 (Saunders & Saunders, 2011).

To summarise, several studies exist that analysed the effects of globally changing consumption, production and trade patterns on agricultural GHG emissions using various methods. The majority of these studies suggested that a global increase in consumption, production and trade of meat and dairy commodities would increase global GHG emissions from agriculture. However, while these studies include the agricultural sector, only a few studies exist that examine the effects for New Zealand's demand, supply and trade of agricultural commodities and the GHG emissions from this.

4.5 Model selection

Arising from the examination of the two main analytical approaches in the previous sections, a PE model was selected for the purpose of this study because it enables detailed and transparent analysis of the agricultural sector with a high level of commodity disaggregation. Specifically, this research uses the Lincoln Trade and Environment Model (LTEM), a PE model that forecasts international trade, production and consumption of agricultural commodities as well as GHG emissions from livestock production.

This model was selected for a number of reasons. Firstly, the LTEM is based on VORSIM (Roningen, 1986; 2012) which is an internationally used framework (e.g., Schwarz, Witzke & Noleppa, 2009; Schluep Campo & Jörin, 2009). The model is readily accessible at the Agribusiness and Economics Research Unit (AERU) at Lincoln University and has been used for several studies focussing on impacts on trade and environment from various policy changes in different countries (e.g., Revell, Saunders, Saunders & Lillywhite, 2013; Saunders, Kaye-Blake & Cagatay, 2009).

Secondly, the country coverage of the model includes the relevant countries of this study; these are New Zealand, China and India. The LTEM was specifically modified to focus on New Zealand, its main trading partners and its policies, e.g., Saunders & Saunders (2011); Saunders et al. (2009); Saunders et al. (2006); Wreford (2006); Rasin (2006); Saunders & Wreford (2004); Wreford & Saunders (2004); Saunders, Cagatay & Wreford (2002); Wijegunawardane (2002). Hence, policies affecting New Zealand can be explicitly modelled with the LTEM.

Thirdly, the LTEM includes extensive disaggregation of the agricultural sector which is much greater than what could be easily achieved with a GE model. For example, the dairy sector in the LTEM consists of five products (liquid milk, butter, cheese, SMP, WMP). This level of commodity disaggregation of the LTEM allows for commodity and country-based policy analyses to be carried out, avoiding many of the issues GE models face at this level of disaggregation such as with data and parameter availability.

Fourthly, the LTEM offers flexibility and transparency in terms of adding variables, equations, policies and data allowing scientific linkages to be relatively easily established.

Finally, and most importantly for this study, the LTEM has the capacity to link international trade to agricultural GHG emissions to inform trade and environment policy negotiations and analysis. As shown in Sections 4.4.1 and 4.4.2, some studies exist that assess impacts of consumption patterns on trade and GHG emissions, however, they often do not examine the effects for New Zealand's demand, supply, and trade of agricultural commodities and the GHG emissions from this. Thus, this research aims to fill this gap and use a model which includes international trade interactions and GHG emissions, particularly for New Zealand.

4.6 Lincoln Trade and Environment Model (LTEM)

In this section, the main characteristics of the LTEM and its structure are described. The environmental sub-module that incorporates GHG emissions for different livestock production systems is also outlined.

4.6.1 Main characteristics of the LTEM

The LTEM is a multi-country, multi-commodity PE framework based upon VORSIM (Roningen, 1996) which followed from SWOPSIM which was used in the last trade negotiations round of the Uruguay Round (Roningen, 1986). It focuses on the agricultural sector and ignores relationships with the rest of the economy. The LTEM includes 21 countries or regions (including the rest of the world (ROW)) and 22 commodities. Commodities are treated as homogenous with regards to physical product characteristics, to country of origin and destination; thus, commodities are perfect substitutes in consumption in international markets. Importers and exporters are assumed to be indifferent about their trade partners. Therefore, it is a non-bilateral model emphasising the net trade of commodities in each region instead of the bilateral trade flows between the countries. However, if required, supply and demand shares of trading countries can be traced back (Revell et al., 2013; Saunders et al., 2006; Cagatay & Saunders, 2003; Saunders, Cagatay & Moxey, 2004).

In the model, the meat sector consists of sheep meat, beef, pig meat and poultry. The dairy sector is disaggregated into five commodities. Raw milk is defined as the farm gate product and is then allocated to the other dairy commodities; this is liquid milk, butter, cheese, whole milk powder (WMP) and skim milk powder (SMP). The crop sector consists of seven products: wheat, sugar, maize, other coarse grains, rice, oilseeds (further refined into oilseed meals and oil). Further sectors included in the model are eggs, wool, kiwifruit and apples (Saunders et al., 2006; Cagatay & Saunders, 2003).

The LTEM uses a synthetic approach to estimate parameters. Supply and demand elasticities are held by the symmetry condition; this implies that own- and cross-price elasticities are consistent (Cagatay et al., 2003).

The model is applied to quantify price, supply, demand and net trade effects of various changes in consumption and/or production patterns and/or policy changes. The LTEM is recursive dynamic, hence it provides short-term solutions using a recursive sequence of temporary equilibria year by year in which changes in stock variables are used to connect two consecutive years. However, medium- to long-term policy impacts are derived in a comparative static fashion with a base year of 2008 and simulating out by 2020 (Saunders et al., 2004).

4.6.2 LTEM structure

The LTEM framework generally includes six behavioural equations and one economic identity for each commodity in each country. These behavioural equations are: domestic supply, domestic demand, domestic stocks, domestic producer and consumer price functions and the trade price equation. The net trade equation is the central economic identity which is equal to excess supply or demand in the domestic economy. Variation exists for commodities based on the levels of disaggregation. For some commodities, the number of behavioural equations may change as total demand is disaggregated into food, feed, and processing industry demand which is determined endogenously (Saunders et al., 2006; Cagatay & Saunders, 2003; Saunders et al., 2004).

In the LTEM, global agricultural markets are assumed perfectly competitive. Supply and demand equations are defined as constant elasticity functions that incorporate both the own and cross-price effects. As shown in Equation 4.1 for commodity (i) and country (j) domestic supply is specified as a function of the supply shifter ($ssft_{ij}$), a policy variable (Z) and producer prices of the own (pp_{ij}) and other substitute and complementary commodities (pp_{kj}) (Cagatay & Saunders, 2003; Saunders et al., 2004).

$$qs_{ij} = f(ssft_{ij}, Z_j, pp_{ij}, pp_{kj}) \qquad (4.1)$$

Domestic demand (qd_{ij}) is defined as a function of the demand shifter ($dsft_{ij}$), consumer prices of the own (pc_{ij}) and other substitute and complementary commodities (pc_{kj}), and per capita real income (pop_j/GDP_j), see Equation 4.2.

$$qd_{ij} = g(dsft_{ij}, pc_{ij}, pc_{kj}, pop_j/GDP_j) \qquad (4.2)$$

The trade price (pt) of a commodity (i) in a country (j) is determined by the world market price ($WDpt_i$) for that commodity and the exchange rate (ex_j), as shown in Equation 4.3. The total effect of world market price on trade price of the country is determined by the price transmission elasticity. Domestic producer (pp_{ij}) and consumer prices (pc_{ij}) are specified as functions of trade price (pt) of a related commodity (i) and commodity specific production and consumption related domestic support/subsidy policies, (Zs_j, Zd_j), which represents the price wedge, see Equations 4.4 and 4.5 (Cagatay & Saunders, 2003; Saunders et al., 2004).

$$pt_{ij} = h(WDpt_i, ex_j) \qquad (4.3)$$

$$pp_{ij} = l(pt_{ij}, Zs_j) \qquad (4.4)$$

$$pc_{ij} = m(pt_{ij}, Zd_j) \qquad (4.5)$$

In the model, stocks ($qst_{ij}^{t=0}$) are determined as the product of stocks from the previous year (qst_{ij}^{t-1}) and the quantity supplied (qs_{ij}) minus the quantity demanded (qd_{ij}) of the commodity (i), as shown in Equation 4.6. Net trade (qt) of a commodity (i) in country (j) is determined as the difference between domestic supply and the sum of domestic demand and stock changes in the related year, see Equation 4.7. The LTEM is a synthetic model since the parameters are taken from the literature (Saunders et al., 2004).

$$qst_{ij}^{t=0} = qst_{ij}^{t-1}(qs_{ij} - qd_{ij}) \qquad (4.6)$$

$$qt_{ij} = qs_{ij} - qd_{ij} - \Delta qst_{ij} \qquad (4.7)$$

For dairy trade, raw milk is not traded because it is assumed to be completely used in the production of the other dairy products, and the supply of liquid milk is assumed to be used in domestic consumption. Commodity supply and demand equations are parameterised to reproduce 2008 base data for each country's price, supply, demand and trade. When consumption and production shifts or consumer and producer support wedges are altered, the model recalculates domestic supply and demand and re-balances world trade, production, consumption and prices. Prices and quantities observed in the base period can then be compared to the new values that emerge from the model (Cagatay & Saunders, 2003; Wijegunawardane, 2002).

4.6.3 Environmental sub-module: incorporating GHG emissions

One important reason for selecting the LTEM for this research is its capacity to link trade to environmental consequences. The environmental sub-module incorporates equations endogenously which simulate GHG emissions from agricultural sub-sectors that are affected by changes in agricultural production in the course of policy and/ or consumption and production changes (Wreford, 2006; Saunders et al., 2006; Cagatay et al., 2003). The environmental sub-module has the capacity to measure GHG emissions from the production of three livestock types (namely dairy, sheep and beef) based on animal numbers. It also has the capability to show the environmental impact of production on groundwater, however this was not included in this study.

In the environmental sub-module, GHG emissions are comprised of methane (CH_4) and nitrous oxide (N_2O) emissions for the dairy, sheep and beef sector in New Zealand, China and India. In order to simulate CH_4 and N_2O emissions associated with livestock production based on animal numbers, separate equations for dairy, sheep and beef are developed for the environmental sub-module of the LTEM. These equations are based on livestock numbers in those sectors and are then converted to GHG emissions (in CO_2-equivalents) based on emission factors (Wreford, 2006; Saunders et al., 2006; Cagatay et al., 2003). Only those sources that are directly related to livestock production are included, that is enteric fermentation and manure management (see Sections 2.2.6 and 3.6.1). Default emission factors provided by FAOSTAT (2013) are used for the calculation of coefficients for New Zealand, China and India.

$$GHG_j = 21(\alpha NA_j) + 310(\gamma NA_j) \qquad (4.8)$$

Equation 4.8 shows how GHG emissions are simulated in the model where αNAj represents CH_4 emissions from animal type j with α showing the CH_4 coefficient which is then multiplied by the GWP, i.e., its CO_2 weighting of 21 to obtain emissions for that specific animal type in CO_2-equivalents. In the equation, the term (γNA_j) represents N_2O emissions from animal type j with γ representing the N_2O coefficient which is then multiplied by its CO_2 weighting of 310 to get the emissions for animal type j in CO_2-equivalents (Wreford, 2006).

4.7 Chapter Summary

This chapter has presented several methods that can be used to estimate the impacts of changes in consumption and production patterns and new trade policies in China and India on international trade and the environment. Trade modelling approaches have been widely used in this research area, therefore this chapter outlined the frameworks for GE and PE models. The chapter then reviewed several studies that used these modelling frameworks to assess the impacts of dietary changes in China and India on international trade and the environment. Each of these models has its own characteristics and for the purpose of this study the PE model is selected as ideally suitable. Overall, modelling results from these studies projected growth in consumption and production of meat and dairy commodities in India and China, and a few studies included its impacts on agricultural GHG emissions. These results will be used to inform scenario selection and where possible they will be compared with results from this research.

The chapter further introduced the LTEM which will be used in this study to model the effects of dietary changes and new trade policies in China and India on New Zealand trade and the environment. It constitutes a recursive dynamic, non-bilateral, multi-country, multi–commodity, synthetic, policy oriented modelling framework. Finally, the chapter described the main characteristics of the model, its structure and the environmental sub-module of the LTEM.

The next chapter of this study will present the data that is used in this research and will develop different scenarios to assess potential impacts of changing consumption, production and trade patterns in China and India on trade and GHG emissions, particularly in New Zealand. It will then describe and evaluate results from these scenarios.

Chapter 5
Data, scenarios & analysis

5.1 Introduction

This chapter outlines the data that was used in this research and introduces scenarios that were simulated. The results from these scenarios are then presented and discussed in comparison with the base scenario.

5.2 Data

The LTEM is underpinned by a considerable amount of data. This includes country specific producer and consumer prices (in US$/t), production and consumption quantities (kilotonnes), beginning and ending stocks (kilotonnes), producer and consumer subsidies and taxes, tariffs and quotas (US$/t). Moreover, the LTEM contains population data and GDP figures for all countries of interest in this research. The base year of the model is 2008 as the latest year available for all data. Historical data is included back to 1986. Data in the model was obtained from a series of databases. These included the FAO Statistical database (FAOSTAT), International Monetary Fund (IMF) Statistical Bulletin, World Bank and the US Department of Agriculture (USDA). Ideally, data would have been obtained from a single source to help ensure consistency; however, time series data for all of the countries in the model was not available from one single database.

As mentioned above, the LTEM is a synthetic model and initial estimates of parameters (e.g., elasticities) are obtained from secondary sources. Elasticities are key parameters in the model since they determine the responsiveness of domestic supply and demand to changing prices, production and consumption patterns and policy measures. Own-price elasticities of demand and supply for beef, sheep meat and dairy commodities for China and India were obtained from mixed sources such as the IMF statistical bulletin, World Bank and USDA. For India, Chinese own-price elasticities of supply and demand were used as a proxy particularly for India's dairy sub-commodities. This was not ideal given that Chinese incomes are higher and different ethnic and religious factors.

Another important coefficient to determine demand in the LTEM is the income elasticities of demand. Income elasticities for beef, sheep meat and five dairy commodities for China and India were obtained from USDA (1998; 2005). These were comparable with income elasticities of demand for China and India from different studies discussed in Sections 2.3.1 and 2.4.1, respectively.

In order to determine the effects on supply and demand, productivity growth rates, GDP growth rates and population growth rates for China and India were obtained from different data sources. Productivity growth rates for India and China were mainly sourced from the IMF (2008) and USDA (2008) which were comparable with productivity growth rates for China and India from the literature presented in Sections 2.3.2 and 2.4.2, respectively. GDP growth rates for India and China were sourced from World Bank (2012b). For China, an annual growth rate of 9 per cent was assumed and India's GPD is estimated to grow by an annual average of 6 per cent to 2020. These growth rates were comparable with those from other studies described in Section 2.2.2. Growth rate projections for population for both countries were derived from World Bank (2012c). It was assumed that India and China's populations would grow annually by 2.1 per cent and 1.1 per cent, respectively.

Similarly, growth rates, own-price elasticities of supply and demand and income elasticities of demand for New Zealand and for other countries were also included in the model. These were sourced from the LTEM database provided by Roningen (2003).

Finally, data required for the calculation of GHG emissions from dairy, beef and sheep was included in the LTEM. This included the total numbers of animals in each country; that is for dairy, beef and sheep (FAOSTAT, 2013). Additionally, emission factors for enteric fermentation and manure management, necessary for calculating GHG emissions from the meat and dairy sector in India, China and New Zealand, were derived from FAOSTAT (2013). The final CH_4 coefficients for enteric fermentation for China, India and New Zealand are given in Appendix Table C.1; and emission factors for the final CH_4 and N_2O coefficients for manure management for each country of interest are attached in Appendix Table C.2.

5.3 Scenarios

Changing consumption and production patterns in India and China are likely to alter global food consumption, agricultural production and international trade of agricultural commodities, as well as global GHG emissions from the livestock sector.

An objective of this research is to assess the effects of changes in meat and dairy consumption and production patterns in India and China on agricultural trade and GHG emissions, particularly in New Zealand. In this regard, three scenarios are used to simulate different consumption and production patterns of meat and dairy commodities in China and India, subsequently referred to as dietary scenarios. As shown in Chapter 2 and 4, difficulties were found in obtaining consistent growth rates for different consumption and production patterns for both countries across all commodities. Growth rates were either available for the countries but not for the level of commodity disaggregation required by the LTEM, or growth rates were provided for only one country and not for the other. Two sources were found that included the most relevant growth rates necessary for scenario development for this study. These were Rosegrant et al. (2001) and the OECD FAO Agricultural Outlook (2013). Both studies provide growth rates for different levels of consumption and production of meat and dairy products for India and China that are used in the first two scenarios of this study. Hence, these scenarios include mixed consumption and production predictions for China and India which reflects the uncertainty around growth and changes in food consumption and production in these countries shown by the literature.

With increased consumption of animal products and declining consumption of cereals, roots and tubers projected for India and China (see Sections 2.3.1 and 2.4.1), dietary patterns in both countries may be converging towards western diets. As mentioned above, a strong driver of this convergence is the growing urban middle class in these countries. In Scenario 3, the partial adoption of US dietary patterns in India and China is simulated. Hence, the level of food consumption in India and China is adjusted to partially reflect US dietary patterns. Unlike Scenario 1 and 2 which focused only on meat and dairy commodities, as these are the main agricultural exports of New Zealand, in this scenario a whole diet change is simulated. While a partial adoption of a US diet in China and India is extreme and unlikely to occur in reality, it does provide some insights into the effects that significant increases in particularly beef and dairy consumption in India and China may have on other countries' food consumption, agricultural production and trade as well as on GHG emissions from livestock.

As for these dietary scenarios, consumption and production changes are applied through shifts in supply and demand functions in the model. These shifts will then shift global excess demand and supply, and the model iterates until the new equilibrium is reached.

Another objective of this research is to simulate the liberalisation of trade policies. This reduction in international trade barriers may also change the patterns of global production, affecting producers and their trade (see Section 2.2.5). In turn, this will affect the amount of GHG emitted by livestock. Thus, two trade scenarios are developed to simulate full trade liberalisation in China and India.

Since its accession to the WTO in 2001, China has pursued further trade liberalisation (see Section 2.3.4). In 2008, New Zealand was the first OECD country to sign a FTA with China. The impact of which is after the base year of the model and therefore unlikely to be fully reflected in the model. However, this should not be significant as changes in tariffs are still ongoing. Since then, China has increased its FTAs with other countries such as Switzerland, Iceland, Chile, and Singapore among others and is in negotiations with several other countries. The reduction of trade barriers to China may change patterns of production, consumption and trade in other countries which is particularly interesting for New Zealand. Thus, full trade liberalisation in China in 2008 is simulated in Scenario 4.

Also, India is currently engaged in several trade negotiations towards bilateral FTAs. This includes negotiations with the European Union, Japan, New Zealand and other South Asian countries, among others (see Section 2.4.4). India's further trade liberalisation may also change the pattern of production, consumption and trade in other countries. Ideally, bilateral trade relations between India and New Zealand would have been modelled to assess potential impacts of a FTA between the two countries, however the model that is used in this research does not only allow for the simulation of bilateral trade relations, thus the final scenario simulates a complete removal of trade barriers in India in 2008. While this situation is unlikely to occur in reality, it does provide some insights into the effect of India's trade policies relative to the baseline scenario.

As for these trade policy scenarios, the trade barriers and subsidies are completely removed in 2008. This will have impacts on price which then generate changes in supply and demand functions which in turn shift global excess demand and supply, and the model iterates until the new equilibrium is reached.

This section presents the five scenarios that are simulated using the LTEM. The scenarios are summarised in Table 5.1; additionally, each scenario is individually discussed in this section and the growth rates for consumption and production of various commodities applied in the three dietary scenarios (Scenario 1 to 3) are presented.

All scenarios simulate from 2008 which is the base year of the model and continue out to 2020.

Table 5.1: Modelling scenarios.

Scenario	Type
BL	Baseline
1.	Increase of meat and dairy consumption and production in India and China (Rosegrant et al., 2001)
2.	Change of meat and dairy consumption and production in India and China (OECD FAO Agricultural Outlook 2013)
3.	Partial adoption of US dietary patterns in China and India
4.	Full trade liberalisation in China in 2008
5.	Full trade liberalisation in India in 2008

5.3.1 Baseline scenario

In the base scenario, the LTEM predicts consumption and production for meat and dairy for India and China from the base year 2008 to 2020. Growth rates for India and China for the baseline were provided with the LTEM database by Roningen (2003). These growth rates are relatively low. They are shown in the second column of Table 5.2 and 5.3, respectively. The tables show that consumption and production are predicted to increase in both countries to 2020. For India, dairy consumption growth rates are relatively small ranging from 6 per cent for milk to 2 per cent for cheese consumption. Growth of India's beef and sheep meat consumption is 3 per cent and 4 per cent, respectively. In contrast, the applied growth rates for production are higher than the consumption shifts, particularly for meat commodities. India's production shifts for beef and sheep meat are 10 per cent and 8 per cent, respectively. In China, baseline growth rates for consumption and production are also relatively small. Changes in consumption range from 4 per cent for sheep meat to 2 per cent for SMP. Similar to India, China's production growth rates are higher than those for consumption. While for example beef consumption is predicted to increase by 3 per cent by 2020, beef production is predicted to increase by 20 per cent.

Table 5.2: Consumption and production shifts of baseline, Scenario 1 and Scenario 2 in India between 2008 – 2020 used in the LTEM.

Commodities	Consumption			Production		
	Baseline	Scenario 1	Scenario 2	Baseline	Scenario 1	Scenario 2
Beef	3%	56%	30%	10%	41%	64%
Sheep meat	4%	52%	32%	8%	43%	28%
Milk (raw)	0%	56%	56%	11%	46%	65%
Milk (liquid)	6%	56%	29%	6%	46%	48%
Cheese	2%	56%	450%	8%	46%	25%
Butter	3%	56%	83%	9%	46%	83%
WMP	3%	56%	280%	5%	46%	15%
SMP	3%	56%	126%	5%	46%	69%

Table 5.3: Consumption and production shifts of baseline, Scenario 1 and Scenario 2 in China between 2008 – 2020 used in the LTEM.

Commodities	Consumption			Production		
	Baseline	Scenario 1	Scenario 2	Baseline	Scenario 1	Scenario 2
Beef	3%	101%	21%	20%	101%	19%
Sheep meat	4%	43%	12%	20%	27%	12%
Milk (raw)	0%	60%	49%	11%	60%	33%
Milk (liquid)	3%	60%	44%	3%	60%	39%
Cheese	0%	60%	58%	10%	60%	37%
Butter	3%	60%	56%	7%	60%	22%
WMP	3%	60%	67%	8%	60%	26%
SMP	2%	60%	174%	6%	60%	14%

5.3.2 Scenario 1 - Increase of meat and dairy consumption and production in China and India (Rosegrant)

In this scenario, the effects of increases in meat and dairy consumption and production in India and China on New Zealand, China and India are estimated. Growth rates for the consumption and production of meat and dairy commodities in both countries were sourced from the study of Rosegrant et al. (2001). The study was described in the literature review in Section 4.4.1. As mentioned above, difficulties were found in obtaining consistent growth rates for India and China across all meat and dairy commodities. Rosegrant et al. (2001) estimated growth rates for meat and dairy consumption and production for India but not for China, thus growth rates from the country group Southeast and East Asia[11] are used to simulate changes in China's

[11] The countries included were Indonesia, Malaysia, Myanmar, Philippines, Thailand, Vietnam, Brunei, Cambodia, Laos, China, Taiwan, Hong Kong, Republic of Korea, Democratic People's Republic Macao and Mongolia.

consumption and production. Since China is by far the largest country in this group, any bias could be expected to be low. Furthermore, Rosegrant et al. (2001) did not provide a disaggregation of dairy commodities into sub-commodities. Thus, for this scenario the same growth rates for milk consumption and production are applied to consumption and production of all dairy commodities of the LTEM. Growth rates from Rosegrant et al. (2001) are annualised and used for the period of 2008 and 2020.

Table 5.2 (third column) illustrates the growth rates for meat and dairy consumption and production in India to 2020 that are used in this scenario. Predicted consumption growth rates for beef and sheep meat are 56 per cent and 52 per cent, respectively. Consumption for all five dairy commodities increases by 56 per cent, each. India's meat and dairy production growth rates are predicted to be smaller than those for consumption. Estimated production increases for all dairy commodities are 46 per cent by 2020 while growth rates for beef and sheep meat production are 41 per cent and 43 per cent, respectively.

Table 5.3 (third column) shows China's growth rates for meat and dairy consumption and production to 2020 that are used in this scenario. Overall, China's consumption and production changes are higher than for India. Beef consumption is predicted to double and sheep meat consumption is predicted to increase by 43 per cent by 2020. Consumption growth rates for all dairy commodities are predicted to rise by 60 per cent by 2020. In China, beef and dairy production is predicted to grow at the same levels than consumption. In contrast, the growth in sheep meat production is lower than consumption growth.

The main purpose of this scenario is to examine the impact of the relatively higher growth rates in meat and dairy consumption and production in India and China on prices, production, producer returns, consumption, net trade and GHG emissions from livestock in China, India and New Zealand.

In accordance to the consumption and production growth rates from Rosegrant et al. (2001) that are used in this scenario, modelling results are expected to show an increase in India's meat and dairy production due to increased prices. This will lead to increased producer returns from all meat and dairy commodities. Also, India's meat and dairy consumption is expected to grow due to the growth rates applied. In the case of net trade, India is expected to remain a net exporter of all commodities. From the rise in production, GHG emissions from India's livestock sector are anticipated to increase. Similarly, China's meat and dairy production is expected to increase relatively to the growth rates used in this scenario. Production growth is a consequence of increased producer prices across all commodities. This is expected to lead to increased producer returns from the meat and dairy commodities. China's consumption of meat and dairy products is expected to grow relatively to the growth rates used in this scenario. China's net trade however is expected to be only slightly affected. Furthermore, the growth in livestock production is expected to lead to increases in GHG emissions from China's livestock sector. Finally, for New Zealand, expected increases in international prices particularly for meat commodities are expected to lead to production growth in the meat sector. Accordingly, producer returns for meat commodities are expected to increase by 2020. In contrast, producer returns for dairy commodities are expected to fall as a consequence of drops in prices and subsequent declines in production. New Zealand's exports of sheep meat are expected to grow due to increased demand. Exports of beef and dairy commodities are expected to be only marginally affected because of increases in global production for these commodities relative to global consumption, and hence there is more supply from other countries on the world market. From the expected growth in meat production, GHG emissions from New Zealand's meat sector are expected to increase while GHG emissions from dairy are expected to fall slightly based on the expected decline in dairy production.

5.3.3 Scenario 2 - Change of meat and dairy consumption and production in China and India (OECD FAO Agricultural Outlook)

In this scenario, a different increase in meat and dairy consumption and production in India and China is assumed. Growth rates for meat and dairy consumption and production in India and China are to follow projections provided in the OECD FAO Agricultural Outlook (2013). Effects of these changes in India's and China's meat and dairy consumption and production on New Zealand, China and India are estimated

The growth rates for meat and dairy consumption and production in India and China used in this scenario are shown in the fourth column of Table 5.2 and 5.3, respectively. Growth rates were available for all countries and on disaggregated commodity-level; hence they were more varied than those used in Scenario 1. For India, consumption changes from the OECD FAO Agricultural Outlook (2013) vary more than the changes used in Scenario 1. In particular, dairy consumption changes are significantly higher than those used in Scenario 1 with cheese consumption increasing 5-fold, a tripling of WMP consumption and doubling of SMP consumption by 2020. India's consumption growth rates for beef and sheep meat are 30 per cent and 32 per cent, respectively. In comparison, these growth rates are lower than the meat consumption changes used in Scenario 1. For most commodities, consumption growth rates are significantly higher than growth rates for production (except for beef). India's dairy production changes range from 69 per cent for SMP to 15 per cent for WMP. Changes in beef and sheep meat production are 64 per cent and 28 per cent, respectively.

As shown in Table 5.3, growth rates for consumption and production in China are generally not as high as growth rates for India. Growth rates used for beef and sheep meat consumption are 21 per cent and 12 per cent, respectively. China's consumption changes for dairy commodities vary more than in Scenario 1; these range from 174 per cent for SMP to 44 per cent for milk. Production growth rates for meat and dairy commodities are lower than the applied growth rates for consumption. This is particularly the case for dairy commodities where production changes range from 39 per cent for milk to 14 per cent for SMP.

The main purpose of this scenario is to enable the assessment of environmental impacts (i.e., GHG emissions) from changes in meat and dairy consumption and production in India and China from growth rates estimated by the OECD FAO Agricultural Outlook (2013). In addition, the effects on New Zealand's producers, net trade and GHG emissions from livestock are assessed in this scenario.

In accordance to the growth rates from the OECD FAO Agricultural Outlook (2013) that are used in this scenario, simulation results are expected to show an increase in meat and dairy production in India as a consequence of increases in prices for all meat and dairy commodities. This is expected to lead to higher producer returns across all meat and dairy commodities. Similarly, meat and dairy consumption is expected to grow relatively to changes used in this scenario. In the case of net trade, India is expected to remain a net exporter of most commodities with beef exports expected to increase significantly. In contrast, India is expected to become a net importer of WMP due to increased domestic demand. With increased production in India's meat and dairy sector, GHG emissions from livestock are expected to rise by 2020. For China, producer returns for meat commodities are expected to drop slightly compared to baseline projections. However, producer returns from dairy commodities are expected to grow as a consequence of increased producer prices and subsequent production growth. Relative to the growth rates used in this scenario, China's meat and dairy consumption is expected to grow. In the case of net trade, China is expected to import more meat and dairy commodities due to increased domestic demand. With an anticipated decline in China's meat production, GHG emissions from this sector are expected to fall. Contrarily, GHG emissions from dairy are expected to rise by 2020. Finally, New Zealand's producer returns for meat and some dairy commodities are expected to grow following increased production relative to higher prices. With regards to trade patterns, New Zealand meat and dairy exports are expected to increase particularly for WMP due to growth in demand. The growth in production is expected to lead to an increase in GHG emissions from the livestock sector in New Zealand.

5.3.4 Scenario 3 - Partial adoption of US dietary patterns in China and India

In this scenario, the effects of a partial adoption of western dietary patterns in China and India on New Zealand, India and China will be assessed. US dietary patterns were selected to represent western dietary patterns in this scenario. While this is an extreme scenario which is unlikely to occur in reality, it does provide some insights into the effects that significant increases in the consumption of particularly beef and some dairy commodities in India and China may have on other countries' consumption, production and trade. Unlike Scenario 1 and 2 where only changes of the consumption and production of meat and dairy commodities are applied, in this scenario the change of a whole diet is simulated. Hence, consumption growth rates for India and China are applied for all 22 commodities in the LTEM to partially reflect US consumption levels. In order to obtain these consumption changes, US per-capita consumption levels for agricultural commodities for 2008 were derived from the LTEM. Percentage differences to India and China's per-capita consumption were calculated and were then used as consumption changes for the projection period. As a total adoption of US dietary patterns in India and China is unlikely to occur by 2020, partial adoption figures (i.e., 10 per cent and 20 per cent of total US per capita consumption) were calculated in order to assess a more realistic scenario. It was then decided to select Option 2 which represents a 20 per cent adoption of US dietary patterns in China and India as this was more realistic to achieve in the projection period. Thus, a gradual consumption change by 2020 is put into the model. Calculations of consumption changes were based on 2008 per-capita consumption levels as this is the base year of the LTEM.

Table 5.4 and 5.5 illustrate China and India's per capita consumption in 2008 in comparison to US per capita consumption in 2008. As mentioned above, consumption changes from Option 2 (i.e., 20 per cent adoption of the US diet) are used in this scenario. For both countries, the general trend is that beef consumption increases significantly (more for India[12] than for China) while sheep meat consumption declines as their kg/head consumption is greater than the 20 per cent of US levels (more for China than for India).

[12] However, with an approximate 80 per cent Hindu population (Government of India. Ministry of Home Affairs, 2001), India's religious affiliations may prevent India reaching 20 per cent of beef intake of a US diet by 2020.

With regards to growth rates for dairy consumption, the tables show that there is a significant growth in China's consumption of all dairy commodities with the exception of WMP which is predicted to decline by 18 per cent by 2020. In contrast, in India only WMP and SMP consumption increases while butter consumption is predicted to decline by 7 per cent by 2020. For both countries, the changes for cheese consumption are very high, thus cheese consumption in both countries is ignored in the modelling assuming that this level was not achievable in the projection period. As mentioned above, in this scenario consumption changes are applied to all 22 commodities in the model as this also reflects other factors such as increases in coarse grains consumption. Again, this is different to Scenario 1 and 2 where only changes to meat and dairy commodities are applied. Also, unlike in Scenario 1 and 2, in this scenario only consumption changes are applied while production was at the baseline growth rates.

Table 5.4: Comparison of US and Chinese per-capita consumption and consumption growth rates used in LTEM.

Commodity	China per capita (kg)	US per capita (kg)	Percentage difference	Option 1: 10% adoption	Option 2: 20% adoption
Wheat	73.15	89.68	23%	2%	5%
Other coarse grains	0.00	16.36	1,636%	164%	327%
Maize	28.32	35.40	25%	3%	5%
Rice	78.76	13.34	-83%	-8%	-17%
Sugar (raw)	11.54	31.40	172%	17%	34%
Sugar[(1)]	0.01	0.01	150%	15%	30%
Oilseeds	2.84	0.00	-100%	-10%	-20%
Oil	18.69	32.16	72%	7%	14%
Beef	4.57	40.96	796%	80%	159%
Pork	34.64	29.01	-16%	-2%	-3%
Sheep meat	2.61	0.52	-80%	-8%	-16%
Poultry	11.64	52.20	348%	35%	70%
Eggs	22.77	14.73	-35%	-4%	-7%
Milk (liquid)	20.53	85.38	316%	32%	63%
Butter	0.13	2.27	1,643%	164%	329%
Cheese	0.30	14.92	4,836%	484%	967%
WMP	0.89	0.10	-89%	-9%	-18%
SMP	0.08	1.50	1,684%	168%	337%

Note: (1) This is used for ethanol production.

Source: LTEM (2008).

Table 5.5: Comparison of US and Indian per-capita consumption and consumption growth rates used in LTEM.

Commodity	India per capita (kg)	US per capita (kg)	Percentage difference	Option 1: 10% adoption	Option 2: 20% adoption
Wheat	67.04	89.68	34%	3%	7%
Other coarse grains	24.70	16.36	-34%	-3%	-7%
Maize	7.11	35.40	398%	40%	80%
Rice	80.75	13.34	-83%	-8%	-17%
Sugar (raw)	21.52	31.40	46%	5%	9%
Sugar (1)	0.00	0.01	0%	0%	0%
Oilseeds	1.25	0.00	-100%	-10%	-20%
Oil	12.89	32.16	149%	15%	30%
Beef	2.00	40.96	1945%	195%	389%
Pork	0.44	29.01	6,535%	653%	1307%
Sheep meat	0.67	0.52	-22%	-2%	-4%
Poultry	2.25	52.20	2,217%	222%	443%
Eggs	2.34	14.73	530%	53%	106%
Milk (liquid)	80.35	85.38	6%	1%	1%
Butter	3.36	2.27	-33%	-3%	-7%
Cheese	0.00	14.92	42,584,274%	4,258,427%	8,516,855%
WMP	0.01	0.10	637%	64%	127%
SMP	0.16	1.50	835%	84%	167%

Note: (1) This is used for ethanol production.

Source: LTEM (2008).

The main purpose of this scenario is to examine the implications for prices, production, producer returns, consumption, net trade and GHG emissions for China, India and New Zealand as a consequence of an extreme change in the consumption of particularly beef and some dairy commodities.

The prior expectations are that India's producer returns will rise significantly for beef and dairy commodities because consumption will cause producer prices and subsequently production to increase by 2020. In contrast, producer returns from sheep meat are expected to decrease as a consequence of drops in producer prices and a subsequent decline in production caused by decreases in sheep meat consumption. India is expected to become a net importer of beef and dairy powders due to increased domestic demand. Again, it is unlikely that India will increase its beef consumption to the level simulated in this scenario for religious reasons. However, as a consequence of increased beef and dairy production, India's GHG emissions from this sector are expected to increase while GHG emissions from sheep are expected to fall following declines in production. Similarly, producer returns in China are expected to rise for most commodities resultant from increased producer prices and subsequent production growth. This is with the exception of sheep meat where an expected decline in production is expected as consumption drops will cause producer prices to fall and producer returns for sheep meat are expected to fall accordingly. China is expected to increase its imports particularly for beef and butter due to increased demand. Exports of sheep meat are expected to grow as consumption is expected fall. Consequently, GHG emissions from sheep are expected to fall while GHG emissions from dairy and beef are expected to rise due to increased production. Finally, India and China's partial adoption of US consumption patterns would also affect New Zealand's producers, trade and GHG emissions through global markets. Producer returns for beef and some dairy commodities are expected to rise resulting from increased prices and subsequent production growth. For sheep meat, drops in production are expected following decreases in prices. This is expected to lead to drops in producer returns for sheep meat in New Zealand. With regards to trade, New Zealand's exports are expected to increase significantly (except for sheep meat) as demand for beef and some dairy commodities are expected to grow significantly. Consequently, from the rise in beef and dairy production an increase in GHG emissions from both sectors is expected. GHG emissions from sheep in New Zealand are expected to fall due to an expected decline in production.

5.3.5 Scenario 4 - Full trade liberalisation in China

This scenario is a trade policy scenario. It provides a picture of the impact of full trade liberalisation for China in 2008 on prices, production, producer returns, consumption, trade and GHG emissions from the dairy and meat sector in India, China and New Zealand. The scenario simulates a complete removal of export subsidies, tariffs, and non-tariff barriers in China in 2008. Trade policies in all other countries in the model remain unchanged.

In 2001, China became a member of the WTO. Since then, China opened up its borders by increasing its number of bilateral trade agreements. In 2008, New Zealand was the first OECD country to sign a FTA with China. Since then, China has signed further FTAs with Switzerland, Iceland, Chile and Singapore among others and is in negotiations with several other countries such as Australia and Norway. The reduction of trade barriers to China may also change the pattern of production, consumption and trade in other countries. Therefore, the main purpose of this scenario is to evaluate the impact of full trade liberalisation in China on prices, production, producer returns, consumption, net trade and GHG emissions from dairy and meat commodities in India, China and New Zealand.

Under full trade liberalisation in China, meat and dairy production is expected to decrease in China. This is due to drops in producer prices as most subsidies and trade barriers encourage higher domestic prices and production. Accordingly, producer returns are expected to fall significantly by 2020. China's consumption of dairy and meat products is expected to increase during the projected period. The decline in meat and dairy production while consumption increases will lead to increased imports of meat and dairy commodities in China. The expected drop in livestock production in China will lead to decreases in GHG emissions from livestock. On the other hand, with a complete removal of China's trade barriers, India and New Zealand are expected to increase meat and dairy production as a consequence of increased producer prices for all commodities. This is expected to lead to increased producer returns for meat and dairy commodities in both countries. Meat and dairy consumption in India and New Zealand is expected to decrease with free trade in China, and meat and dairy exports are expected to increase. As a consequence of increased meat and dairy production, GHG emissions from both sectors are expected to increase in India and New Zealand by 2020.

5.3.6 Scenario 5 - Full trade liberalisation in India

The final scenario is also a trade policy scenario. It simulates a complete removal of India's trade barriers, i.e., export and import taxes, export subsidies, tariffs, production quota, and intervention prices in the base year of 2008 while trade policies in all other countries in the model remain unchanged. While this situation is unlikely to occur in reality, it does provide some insights into the effect of India's trade policies relative to the baseline scenario. Ideally, bilateral trade relations between India and New Zealand would be modelled to simulate the effects of a potential FTA between the two countries, however a simulation of full trade liberalisation in India is used as the final scenario of this research because the LTEM is not a bilateral model.

Thus, the main purpose of this scenario is to assess the impact of full trade liberalisation in India in 2008 on prices, production, producer returns, consumption, net trade and GHG emissions from dairy and meat commodities in India, China and New Zealand.

Under its full trade liberalisation meat and dairy production in India is expected to fall due to decreased producer prices for those commodities as most subsidies and trade barriers promote higher domestic prices and production. As a consequence, producer returns from meat and dairy commodities are expected to fall significantly by 2020. For India, it is expected that meat and dairy consumption will increase, and thus net imports are expected to increase. The anticipated decrease in India's livestock production will lead to a drop in GHG emissions from livestock.

For China and New Zealand, the complete removal of trade barriers in India in 2008 is expected to increase producer returns in both countries as a consequence of higher producer prices and subsequent production growth across all meat and dairy commodities. Meat and dairy consumption is expected to fall in China and New Zealand caused by higher prices. New Zealand is expected to increase meat and dairy exports significantly due to increased demand. China is expected to increase exports of beef, sheep meat, cheese and WMP and decrease its SMP and butter imports. Consequently, GHG emissions from the anticipated increase in livestock production in China and New Zealand are expected to rise by 2020.

5.4 Results

This section evaluates the results of the five scenarios described above. The LTEM includes 21 countries or regions (including the rest of the world) and 22 commodities. The interaction of all countries and commodities in the model produces a large volume of output. However, presentation of results is limited to those directly relevant to the scope of this thesis. This is for the three countries of interest: India, China and New Zealand and for the commodities: sheep meat, beef, cheese, butter, SMP and WMP. For these countries and commodities variables reported here are production, producer returns, consumption and net trade. Producer returns refer to the total return earned by the producers and are calculated by multiplying the quantity of a commodity produced in a country by its price. For net trade, a negative value indicates that the commodity is a net import while a positive value represents net export quantities. Finally, the change in GHG emissions (in CO_2 –equivalents) from three livestock sectors (i.e., dairy, beef and sheep meat) are presented.

Results of all scenarios are compared to the baseline; they are presented as percentage changes from the base with the exception of net trade which is presented in kilotonnes. For each scenario, the percentage changes in 2020 compared to the baseline in 2020 are shown, first by impacts on production, producer returns, consumption and net trade from the meat and dairy sector; and then the GHG emissions from dairy, beef and sheep in the three countries of interest are described.

5.4.1 Scenario 1 - Increase of meat and dairy consumption and production in China and India (Rosegrant)

The first scenario assumed an increase in meat and dairy consumption and production in India and China using growth rates from Rosegrant et al. (2001). Results presented in Table 5.6 show that China's production of meat and dairy commodities is predicted to increase significantly for all commodities due to increased producer prices. Increases range from a doubling of SMP production to a 12 per cent increase of sheep meat production. Generally, the production growth levels predicted by the model are consistent with the growth rates from Rosegrant et al. (2001) that were used in this scenario.

Growth in producer prices and production lead to significant increases in producer returns for all meat and dairy commodities. The predicted increase in producer returns for dairy commodities were the highest for SMP which are expected to more than double by 2020, this is followed by returns for cheese (+89 per cent) and beef (+82 per cent). China is expected to have the highest predicted increase in producer returns of all countries in this scenario. As expected from the growth rates used in this scenario, results indicated that meat and dairy consumption in China is predicted to grow significantly by 2020 compared to the baseline. In particular, beef consumption is expected to almost double by 2020 which is consistent with the growth rate used in this scenario. This result is comparable to Huang et al. (1999). In their study, they predicted a doubling of meat consumption by 2020. However, this did include poultry and pork products. Under this scenario, the highest increase in the consumption of dairy products is predicted for butter consumption which is expected to increase by 66 per cent by 2020 and is slightly above the growth rate applied. With regards to net trade, China is predicted to become a net importer of sheep meat by 2020. It remains a net exporter of beef, cheese and WMP.

As a result of the predicted increases in China's meat and dairy production, GHG emissions from all livestock types are expected to increase significantly by 2020. The greatest increase is predicted for GHG emissions from beef (+79 per cent), followed by GHG emissions from dairy (+21 per cent), then GHG emissions from sheep (+12 per cent). These results are comparable with Verburg et al. (2009). In their study, simulations predicted a significant growth in China's meat production and consequently a large increase in global GHG emissions.

For India, modelling results predicted meat and dairy production to increase significantly by 2020. This is a consequence of increased producer prices for meat and dairy commodities. India's beef and sheep meat production is predicted to grow by 30 per cent and 40 per cent, respectively. Also, significant growth is predicted for the production of dairy commodities, particularly for SMP where production is predicted to almost double by 2020. The growth in India's production was expected from the growth rates applied in this scenario.

Higher producer prices and the subsequent growth in production lead to significant increases in producer returns from all meat and dairy commodities in India. Producer returns from sheep meat are predicted to increase 50 per cent relative to the baseline by 2020. This is the highest increase of all countries in this scenario. Returns from beef commodities are expected to grow by 32 per cent. Returns from dairy commodities are also predicted to increase significantly by 2020 with the highest increase predicted for SMP (+86 per cent), followed by cheese (+71 per cent), then butter (+55 per cent). However, overall, increases in producer returns for meat and dairy commodities in India are not as high as those predicted for China in this scenario.

Table 5.6: Scenario 1 – Impacts of increases in meat and dairy consumption and production in India and China for China, India and New Zealand in 2020.

Measure	Commodities	China	India	New Zealand
Production quantities as percentage change to base in 2020	Beef	79.28	29.88	-0.01
	Sheep meat	12.08	40.30	7.87
	Butter	81.32	65.39	-3.08
	Cheese	88.63	69.97	-2.47
	WMP	80.01	63.74	-3.48
	SMP	99.64	79.39	-2.61
Producer returns as percentage change to base in 2020	Beef	81.75	31.67	1.37
	Sheep meat	19.93	50.13	15.43
	Butter	70.18	55.23	-9.03
	Cheese	89.18	70.47	-2.19
	WMP	69.23	53.94	-9.26
	SMP	106.82	85.84	0.89
Consumption quantities as percentage change to base in 2020	Beef	96.56	51.62	0.40
	Sheep meat	32.60	41.58	-3.66
	Butter	65.90	57.22	2.87
	Cheese	60.06	52.75	0.05
	WMP	58.92	57.8	2.53
	SMP	47.06	100.43	-1.40
Net Trade quantities in baseline in 2020 in kilotonnes	Beef	1,049.90	847.86	473.76
	Sheep meat	545.99	56.49	510.39
	Butter	-26.71	223.15	355.9
	Cheese	8.68	0.87	387.08
	WMP	46.99	0.29	717.55
	SMP	-49.97	32.67	356.82
Net trade quantities in scenario in 2020 in kilotonnes	Beef	796.67	588.99	473.2
	Sheep meat	-131.01	69.07	560.54
	Butter	-20.87	691.26	343.15
	Cheese	131.73	1.48	376.86
	WMP	342.03	1.39	692.35
	SMP	-39.48	18.98	347.16
GHG emissions (CO_2-equ.) as percentage change to base in 2020	Dairy	21.39	22.9	-2.51
	Beef	79.29	29.9	-0.01
	Sheep	12.08	40.3	7.87

Note: Absolute amounts of modelling results from this scenario are attached in Appendix Table D.1.

As shown in Table 5.6 and as anticipated from the growth rates used in this scenario, India's consumption of meat and dairy products is predicted to increase significantly. Increases range from a doubling of SMP consumption to an increase of 42 per cent in sheep meat consumption by 2020. Consumption grows to similar levels than the growth rates applied in this scenario. Despite this large increase in consumption, India remains a net exporter of all meat and dairy commodities by 2020. While exports of beef, sheep meat and SMP are predicted to decrease by 2020, exports of butter, cheese and WMP are expected to increase. With regards to simulations of GHG emissions from livestock in India, growth is predicted for GHG emissions from all commodities at sheep meat (+40 per cent), followed by beef (+30 per cent), then dairy (+23 per cent). The growth in GHG emissions from livestock is a consequence of the expected growth in meat and dairy production.

In this scenario, predicted impacts on New Zealand's production, producer returns, consumption, net trade and GHG emissions are relatively small compared to those predicted for India and China. As shown in Table 5.6, results predict New Zealand's sheep meat production to grow by 8 per cent by 2020 while beef production is predicted to be only marginally affected. Interestingly, dairy production is predicted to decline by 3 per cent for butter, cheese, SMP and WMP. This is due to declines in producer prices for these commodities. These drops in producer prices and the subsequent decline in production lead to small decreases in producer returns for butter, cheese and WMP. Predicted declines range from 2 per cent for cheese to 9 per cent for WMP. Importantly, New Zealand producer returns for meat commodities are predicted to increase as a consequence of increased production relative to higher prices. In particular, returns from sheep meat are expected to grow by 15 per cent. In contrast, producer returns from beef are expected to increase by 1 per cent by 2020.

Results further indicate that beef consumption in New Zealand is predicted to remain unchanged while sheep meat consumption is predicted to fall by 4 per cent due to increased prices. Consumption of dairy products is expected to increase slightly as a consequence of drops in dairy prices. In terms of net trade, sheep meat exports are predicted to increase following the growth in production while consumption declines. New Zealand beef exports are predicted to remain unchanged while dairy exports are predicted to decline slightly by 2020. This is due to the fact that New Zealand's dairy production is predicted to decrease while consumption is predicted to grow.

With regards to GHG emissions from livestock, New Zealand has a predicted reduction in GHG emissions from dairy (-3 per cent). While GHG emissions from beef production are predicted to remain unchanged, GHG emissions from sheep meat production are expected to increase by 8 per cent by 2020.

In summary, results on producer returns of all countries are mainly consistent with the expectations presented in Section 5.3.2. Both higher producer prices and subsequent production growth of meat and dairy commodities in China and India lead to higher producer returns from these commodities in both countries. For New Zealand, as expected, increases in producer returns are predicted for both meat commodities. Unexpectedly, in New Zealand returns from most dairy commodities are predicted to fall. This is a consequence of declines in producer prices and subsequent drops in production of most dairy commodities. In terms of net trade, as expected, India remains a net exporter of all meat and dairy commodities while China becomes a net importer of sheep meat in addition to its existing butter and SMP imports. As a consequence of growth in demand, New Zealand exports of sheep meat are predicted to increase while beef exports mostly remain unchanged. Dairy exports decline slightly. Finally, the changes in GHG emissions from livestock are predicted to increase significantly in China and India for all three livestock sectors following an increase in meat and dairy production. For New Zealand, as expected, GHG emissions from sheep are predicted to rise due to an increase in production. In contrast, GHG emissions from beef are predicted to remain unchanged while GHG emissions from dairy are predicted to decline slightly by 2020.

5.4.2 Scenario 2 - Change of meat and dairy consumption and production in China and India (OECD FAO Agricultural Outlook)

The second scenario assumed changes in meat and dairy consumption and production using growth rates from the OECD FAO Agricultural Outlook (2013). Results presented in Table 5.7 illustrate that China's dairy production is predicted to increase significantly by 2020, particularly cheese and WMP production growing by 46 and 42 per cent, respectively. This growth was expected from the growth rates used in this scenario. In contrast, the production of sheep meat and beef is expected to decline slightly by 2020. Both, increased producer prices and subsequent production growth of dairy commodities lead to significant increases in producer returns from dairy by 2020. Predicted increases range from 48 per cent for WMP to 7 per cent for butter. In comparison, the increases in China's producer returns for dairy commodities in this scenario are lower than predicted increases of producer returns for dairy simulated in Scenario 1. The results further indicate a slight decline in producer returns for both meat commodities in China by 2020.

Table 5.7: Scenario 2 – Impacts of changes in meat and dairy consumption and production in China and India for China, India and New Zealand in 2020.

Measure	Commodities	China	India	New Zealand
Production quantities as percentage change to base in 2020	Beef	-1.37	50.13	0.03
	Sheep meat	-5.58	24.5	4.40
	Butter	20.02	105.39	-0.21
	Cheese	45.56	44.07	0.74
	WMP	41.61	40.80	1.39
	SMP	28.35	120.35	0.57
Producer returns as percentage change to base in 2020	Beef	-0.77	51.05	0.65
	Sheep meat	-1.77	29.53	8.62
	Butter	6.83	82.82	-11.18
	Cheese	46.15	44.65	1.14
	WMP	48.07	47.22	6.02
	SMP	40.13	140.57	9.80
Consumption quantities as percentage change to base in 2020	Beef	17.62	25.98	0.41
	Sheep meat	5.06	23.94	-2.13
	Butter	68.82	88.8	5.37
	Cheese	57.77	446.79	-0.22
	WMP	56.08	268.68	-1.72
	SMP	151.17	113.42	-3.45
Net Trade quantities in baseline in 2020 in kilotonnes	Beef	1,049.9	847.86	473.76
	Sheep meat	545.99	56.49	510.39
	Butter	-26.71	223.15	355.97
	Cheese	8.68	0.87	387.08
	WMP	46.99	0.29	717.55
	SMP	-49.97	32.67	356.82
Net Trade quantities in Scenario in 2020 in kilotonnes	Beef	-158.41	1,841.93	473.46
	Sheep meat	130.33	74.76	538.5
	Butter	-119.32	1,113.4	353.35
	Cheese	-36.67	1.09	390.2
	WMP	-110.00	-34.89	727.63
	SMP	-204.94	85.04	360.35
GHG emissions (CO_2 –equ.) as percentage change to base in 2020	Dairy	12.52	23.06	0.66
	Beef	-1.37	50.14	0.03
	Sheep	-5.58	24.50	4.40

Note: Absolute amounts of modelling results from this scenario are attached in Appendix Table D.2.

As expected from the growth rates from the OECD FAO Agricultural Outlook (2013) that were used in this scenario, modelling results for China's meat and dairy consumption show a significant increase across all meat and dairy commodities. In particular, SMP consumption is predicted to more than double by 2020. In the case of net trade, China is predicted to change from a net exporter of beef, cheese and WMP to a net importer of those commodities due to a significant increase in domestic demand. Additionally, imports of butter and SMP are predicted to increase by 2020. However, China is predicted to remain a net exporter of sheep meat. As a consequence of the growth in dairy production in China, model results indicate a significant increase in GHG emissions from this sector with emissions from dairy predicted to rise 13 per cent relative to the baseline. With an anticipated decline in China's meat production, GHG emissions from sheep are expected to drop by 6 per cent while GHG emissions from beef are predicted to fall by 1 per cent.

For India, modelling results indicate significant increases in dairy production by 2020 resulting from increased prices. The highest increase is predicted for SMP production (+120 per cent), then butter production (+105 per cent). Similarly, a large increase in beef production is predicted, rising 50 per cent during the projection period. This is followed by an increase in sheep meat production of 25 per cent by 2020. The predicted growth in production is in line with the growth rates from the OECD FAO Agricultural Outlook (2013) that were used in this scenario.

Higher prices and subsequent production growth lead to significant increases in producer returns from India's meat and dairy sector. Producer returns for SMP are predicted to more than double and returns for butter are expected to increase by 83 per cent over the projection period. Among meat commodities, the highest increase is predicted for producer returns for beef, rising 51 per cent relative to the baseline.

As shown in Table 5.7, India's consumption of meat and dairy commodities is predicted to increase significantly by 2020. This was expected from the growth rates applied in this scenario. Cheese consumption is expected to increase 5-fold, consumption of WMP is predicted to more than triple and SMP consumption is predicted to more than double by 2020. India's consumption of beef and sheep meat is expected to increase by 25 per cent and 23 per cent, respectively. In the case of net trade, results show that India is predicted to remain a net exporter of most commodities. Exports are significantly higher than in the baseline, particularly for beef and butter. In contrast, India becomes a net importer for WMP by 2020 due to increased domestic demand.

As a result of significant increases in production in both sectors, GHG emissions from livestock are predicted to increase significantly in India. The model predicted the highest increase for GHG emissions from beef (+50 per cent), followed by GHG emissions from sheep meat (+25 per cent), then dairy emissions (+23 per cent). In comparison, India has significantly higher increases in GHG emissions from the meat and dairy sector than China in this scenario.

For New Zealand, the impacts on production, producer returns, consumption, and net trade from changes in India's and China's consumption and production patterns are positive but relatively small compared to impacts predicted for China and India. New Zealand's production is predicted to increase for most meat and dairy commodities, ranging from 4 per cent for sheep meat to 1 per cent for SMP. Beef and butter production is only marginally affected. New Zealand's producer returns for meat and some dairy commodities are predicted to increase in turn of production growth relative to higher prices. Increases in producer returns range from 10 per cent for SMP to 1 per cent for beef. Producer returns from butter are predicted to drop by 11 per cent which is a consequence of a fall in the butter price and a subsequent drop in production. Compared to Scenario 1, increases in New Zealand producer returns for meat and dairy commodities are generally higher.

Results further show that New Zealand's consumption of dairy and beef commodities are predicted to decline by 2020 resulting from increased prices. The only increase is predicted for butter consumption which is expected to grow by 5 per cent over the projection period due to falls in prices. With regards to trade, New Zealand's meat and dairy exports are expected to increase due to growth in demand, particularly WMP exports. In contrast, butter exports are expected to drop following falls in production while consumption rises. As a consequence of the predicted increases in production, GHG emissions from dairy and sheep meat are expected to increase slightly by 2020 while there is no change predicted for GHG emissions from beef production.

In summary, modelling results for producer returns for beef, sheep meat and dairy commodities are consistent with the expectations described in Section 5.3.3. For India, China and New Zealand, producer returns for most meat and dairy commodities are predicted to increase by 2020 as a consequence of higher producer prices and subsequent production growth. In terms of net trade, as expected, India is predicted to become a net importer of WMP while China will become a net importer of beef and all dairy commodities by 2020. As expected, New Zealand remains net exporter for all commodities with predicted increases in most meat and dairy commodities. However, drops in beef and butter exports are predicted. Finally, the results for GHG emissions in China, India and New Zealand are consistent with the expectations. Following the growth in production, GHG emissions from livestock are predicted to increase in India and New Zealand. For China, GHG emissions from the meat sector are predicted to fall which is in line with modelling expectations.

5.4.3 Scenario 3 - Partial adoption of US dietary patterns in China and India

The third scenario assumed a partial adoption of US consumption patterns in China and India by 2020. Unlike in Scenario 1 and 2, changes for all 22 commodities in the model were applied to Indian and Chinese consumption (with the exception of cheese) while production growth rates were at the baseline growth rates. Results presented in Table 5.8 show that China's beef and dairy production is predicted to increase significantly by 2020 following increased producer prices. Increases range from 53 per cent for SMP production to 15 per cent for beef production. Although production growth rates were held at baseline growth rates, production grew at a higher rate. These changes were expected because the increase in consumption causes producer prices to change and thus production. In contrast, sheep meat production is predicted to decline by 3 per cent by 2020 due to a drop in price. As a consequence of higher prices and subsequent growth in production, increases of China's producer returns for beef and dairy commodities by 2020 are predicted. For dairy, producer returns for SMP are expected to almost double, this is followed by an increase of 32 per cent for returns from butter. For meat commodities, producer returns from beef are predicted to increase by 40 per cent during the projection period while returns from sheep meat are expected to fall by 3 per cent following drops in production relative to falls in prices.

Consistent with the growth rates used in this scenario, modelling results show that China's beef consumption is predicted to more than double by 2020. Higher growth levels are predicted for butter and SMP consumption. Butter consumption is expected to quadruple while SMP consumption is predicted to triple. Also consistent with the growth rates used in this scenario, is the predicted drop in sheep meat and WMP consumption by 12 per cent and 6 per cent, respectively. In terms of net trade, China is predicted to become a net importer of beef due to increased domestic demand. Also, China is predicted to increase imports of dairy, particularly imports of SMP and butter. China's exports of sheep meat and WMP are predicted to grow significantly by 2020 as a consequence of increased production while consumption drops.

With a predicted decline in China's sheep meat production, GHG emissions from this sector are predicted to fall by 3 per cent by 2020. In contrast, GHG emissions from dairy and beef are predicted to increase significantly by 2020 with the highest growth predicted for dairy (+27 per cent), then beef (+15 per cent).

Table 5.8: Scenario 3 –Impacts of a partial adoption of US consumption patterns of dairy and meat products in India and China for China, India and New Zealand in 2020.

Measure	Commodities	China	India	New Zealand
Production quantities as percentage change to base in 2020	Beef	15.39	10.73	14.04
	Sheep meat	-2.73	-1.01	-2.43
	Butter	29.02	1.81	5.07
	WMP	16.54	-7.15	1.43
	SMP	52.99	22.81	5.01
Producer returns as percentage change to base in 2020	Beef	39.50	34.01	38.02
	Sheep meat	-2.86	-1.14	-2.56
	Butter	31.74	3.96	7.29
	WMP	9.02	-13.14	-5.11
	SMP	90.16	52.65	30.53
Consumption quantities as percentage change to base in 2020	Beef	128.87	329.28	-9.98
	Sheep meat	-11.58	2.82	3.60
	Butter	329.49	-4.95	-0.80
	WMP	-5.82	131.59	3.84
	SMP	261.73	136.79	-8.33
Net trade quantities in baseline in 2020 in kilotonnes	Beef	1,049.9	847.86	473.76
	Sheep meat	545.99	56.49	510.39
	Butter	-26.71	223.15	355.97
	WMP	46.99	0.29	717.55
	SMP	-49.97	32.67	356.82
Net trade quantities in scenario in 2020 in kilotonnes	Beef	-5,920	-6,566.3	569.75
	Sheep meat	851.40	25.54	492.73
	Butter	-571.79	494.12	375.8
	WMP	327.57	-21.22	727.7
	SMP	-315.76	-174.57	379.52
GHG emissions (CO_2-equ) as percentage change to base in 2020	Dairy	26.63	-1.21	2.51
	Beef	15.40	10.74	14.05
	Sheep	-2.74	-1.02	-2.39

Note: Absolute amounts of modelling results from this scenario are attached in Appendix Table D.3.

In the case of India, the model shows an increase in the production of most meat and dairy commodities, ranging from 23 per cent for SMP to 2 per cent for butter. However, the production of WMP and sheep meat is predicted to fall by 7 per cent and 1 per cent, respectively. These drops are due to declines in producer prices for these commodities. In particular, the drop in WMP production was an unexpected result and could be explained by the allocation of raw milk to dairy commodities (namely cheese, butter, WMP, SMP) in the model. This study used the allocation of raw milk to other dairy commodities that was provided by Roningen (2003). This allocation is based on historical data and might have changed over time. As a consequence of falls in producer prices and subsequent declines in production, producer returns for WMP and sheep meat are predicted to fall by 13 per cent and 1 per cent, respectively. In addition, results show an increase of India's producer returns for beef, butter and SMP resulting from growth in production relative to higher prices. However, these increases are slightly smaller than for China in this scenario. The highest increase is predicted for India's producer returns from SMP (+53 per cent), followed by returns from beef (+34 per cent).

Model results further predict an increase in India's consumption for most dairy and meat commodities with the highest increase predicted for beef consumption which is expected to quadruple by 2020. This increase is higher than the predicted increase for China's beef consumption in this scenario but was expected from the growth rates used in this scenario. This is followed by a predicted doubling of India's SMP and WMP consumption, each.

The large increase in beef consumption is predicted to have a major impact on India's beef trade. Under this scenario, India becomes a large net importer of beef, WMP and SMP that it previously exported. In particular, the transfer from a net beef exporter to a net beef importer is highly unrealistic due to India's religious affiliations. Furthermore, India remains a net exporter of sheep meat and butter.

As a consequence of the predicted decline in WMP and sheep meat production, a small decrease in GHG emissions from both sectors are predicted for the projection period. In contrast, GHG emissions from beef are predicted to rise by 11 per cent by 2020 in the course of increased beef production.

Finally, India and China's partial adoption of US consumption patterns also affects New Zealand's producers. Following increased producers prices for beef and some dairy commodities, New Zealand's production is predicted to increase for most commodities (except sheep meat). Increases range from 14 per cent for beef production to 1 per cent for WMP production. Similar to China, only sheep meat production is predicted to drop by 2 per cent by 2020 due to a decline in the producer price. This leads to declines in producer returns from sheep meat by 3 per cent by 2020. However, results indicate significant gains in New Zealand producer returns from beef. These are predicted to increase by 38 per cent by 2020. In addition, significant increases in producer returns from SMP (+30 per cent) and butter (+7 per cent) are simulated. In contrast, New Zealand producer returns for WMP are predicted to fall by 5 per cent as a consequence of drops in WMP price and subsequent declines in production.

Table 5.8 shows that New Zealand's consumption of sheep meat and WMP products are predicted to increase by 4 per cent, each. As expected, results indicate declines in New

Zealand's consumption of beef (-10 per cent), SMP (-9 per cent) and butter (-1 per cent) by 2020 due to increased prices. With regards to trade, New Zealand's exports are predicted to increase significantly with large increases predicted for beef, butter and dairy powders. However, sheep meat exports are predicted to drop slightly due to decreased demand. Consequently, from the rise in beef and dairy production in New Zealand an increase in GHG emissions from both sectors is predicted. Results show an increase in GHG emissions from beef by 14 per cent while GHG emissions from dairy are predicted to increase by 3 per cent by 2020. GHG emissions from sheep are predicted to drop by 2 per cent due to an expected drop in production.

In summary, the results from this analysis support the expectations for producer returns in India, China and New Zealand described in Section 5.3.4. Producer returns for beef and dairy commodities are predicted to increase in India, China and New Zealand while returns from sheep meat are expected to fall. In terms of net trade, as expected, India and China are predicted to become large beef net importers while New Zealand beef exports are predicted to increase significantly. As further expected, India is predicted to become an importer of beef, SMP and WMP by 2020 while China will become a net importer of beef and all dairy commodities. New Zealand beef and dairy exports are predicted to grow with significant increases predicted for beef exports which is in line with the expectations. Similarly, the results for GHG emissions from the livestock sector in China, India and New Zealand are consistent with the expectations. GHG emissions from sheep are predicted to decline in all countries, and an increase in beef emissions in all countries is expected. GHG emissions from the dairy sector are predicted to increase in China and New Zealand while India's dairy emissions are predicted to drop due to declines in WMP production.

5.4.4 Scenario 4 - Full trade liberalisation in China

This scenario assumed a complete removal of China's export subsidies, tariffs, production quota, and intervention prices in the base year of 2008 while trade policies in all other countries in the model remain unchanged. Results presented in Table 5.9 show that free trade in China would lead to decreases in the country's meat and dairy production as a result of declines in producer prices across all meat and dairy commodities. Predicted declines range from 19 per cent for cheese production to 4 per cent of sheep meat production. Accordingly, significant declines in producer returns from all meat and dairy commodities are predicted, ranging from 31 per cent for cheese to 13 per cent for sheep meat. As a consequence of drops in prices, China's consumption of meat and dairy commodities is predicted to increase by 2020 with the highest increase predicted for cheese consumption (+11 per cent), this is followed by an increase in beef consumption (+9 per cent). With regards to net trade, imports are expected to increase for sheep meat and butter, and China is predicted to become a net importer of beef, cheese and WMP.

Table 5.9: Scenario 4 – Impacts of full trade liberalisation in China in 2008 for India, China and New Zealand in 2020.

Measure	Commodities	China	India	New Zealand
Production quantities as percentage change to base in 2020	Beef	-9.85	0.87	1.09
	Sheep meat	-4.11	2.15	4.23
	Butter	-12.97	-0.22	1.83
	Cheese	-18.53	0.48	1.83
	WMP	-10.84	4.16	2.45
	SMP	-12.65	0.41	1.76
Producer returns as percentage change to base in 2020	Beef	-22.46	2.91	3.17
	Sheep meat	-12.98	6.23	8.39
	Butter	-25.09	0.49	2.56
	Cheese	-31.40	1.19	2.55
	WMP	-15.20	8.98	7.18
	SMP	-20.29	0.80	2.16
Consumption quantities as percentage change to base in 2020	Beef	9.08	-1.20	-0.08
	Sheep meat	6.71	-2.37	-1.67
	Butter	9.82	-0.28	-0.28
	Cheese	10.75	-0.39	-0.19
	WMP	5.03	-2.23	-1.77
	SMP	7.18	-0.19	-0.16
Net trade quantities in baseline in 2020 in kilotonnes	Beef	1,049.9	847.86	473.76
	Sheep meat	545.99	56.49	510.39
	Butter	-26.71	223.15	355.97
	Cheese	8.68	0.87	387.08
	WMP	46.99	0.29	717.55
	SMP	-49.97	32.67	356.82
Net trade quantities in scenario in 2020 in kilotonnes	Beef	-242.94	903.99	480.35
	Sheep meat	131.89	93.49	537.14
	Butter	-64.00	225.04	363.18
	Cheese	-111.17	0.87	394.73
	WMP	-151.86	1.29	735.25
	SMP	-66.39	33.93	363.78
GHG emissions (CO_2-equ.) as percentage change to base in 2020	Dairy	-6.58	0.01	1.70
	Beef	-9.85	0.87	1.09
	Sheep	-4.11	2.15	4.22

Note: Absolute amounts of modelling results from this scenario are attached in Appendix Table D.4.

As a consequence of the predicted decrease in meat and dairy production in China, declines in GHG emissions from livestock are expected. The highest drop is predicted for GHG emissions from the beef sector (-10 per cent), this is followed by a decline in GHG emissions from dairy (-7 per cent). GHG emissions from sheep meat are predicted to decrease by 4 per cent compared to the baseline.

Free trade in China is predicted to also affect India's production, consumption, net trade and GHG emissions from the meat and dairy sector. India's meat and dairy production is expected to increase slightly (except for butter) under free trade in China due to increased prices. The highest production growth is predicted for WMP increasing 4 per cent by 2020, this is followed by an increase of 2 per cent of sheep meat production. As a consequence of higher prices and subsequent growth in production across all meat and dairy commodities, producer returns in India are predicted to increase over the projection period. Increases range from 9 per cent from WMP to 1 per cent from SMP. In contrast, producer returns for sheep meat are predicated remain unchanged. As anticipated from the increase in prices, meat and dairy consumption in India is predicted to slightly decrease by 2020. In the case of net trade, results indicate that India increases its exports for all meat and dairy commodities during the projection period.

The growth in India's meat and dairy production is predicted to lead to slight increases in GHG emissions from both sectors. The highest increase is predicted for GHG emissions from sheep (+2 per cent), followed by GHG emissions from beef (+1 per cent). GHG emissions from dairy are expected to remain unchanged over the projection period

For New Zealand, fully liberalising trade in China results in slight increases in meat and dairy production, ranging from 4 per cent from sheep meat production to 1 per cent from beef production. This is due to a slight increase in producer prices for meat and dairy commodities in New Zealand. As a consequence of production growth relative to higher prices, increases in producer returns across all meat and dairy commodities in New Zealand are predicted with the highest increase expected for returns from sheep meat (+8 per cent), then WMP (+7 per cent). Predicted increases in New Zealand producer returns are generally higher than those for India. Meat and dairy consumption is expected to marginally decrease across all meat and dairy commodities by 2020 due to higher prices. In terms of net trade, New Zealand is predicted to increase meat and dairy exports significantly by 2020, particularly for sheep meat.

As a consequence of increased meat and dairy production in New Zealand, GHG emissions from the meat and dairy sector are predicted to increase. GHG emissions from sheep are predicted to rise by 4 per cent, this is followed by an increase in GHG emissions from dairy by

2 per cent, then an increase of GHG emissions from beef by 1 per cent. In comparison, New Zealand shows slightly higher increases in GHG emissions from sheep and dairy than India in this scenario.

In summary, results from full trade liberalisation in China in 2008 are consistent with the expectations for production, producer returns, consumption, net trade and GHG emissions presented in Section 5.3.5; significant declines for China's production, producer returns and exports are predicted. As a consequence of the decrease in meat and dairy production, China's GHG emissions from livestock are predicted to fall during the projection period. Similarly, the expectations for India and New Zealand are supported in this analysis with both countries predicted to experience increases in producer returns and exports of meat and dairy commodities. However, as a consequence of increased meat and dairy production, GHG emissions from livestock are predicted to slightly increase in India and New Zealand by 2020.

5.4.5 Scenario 5 - Full trade liberalisation in India

The final scenario assumed full trade liberalisation in 2008. Therefore, India's export and import taxes, export subsides, tariffs, production quota, and intervention prices were removed completely while trade policies in all other countries in the model remain unchanged. Results presented in Table 5.10 show a decline in India's production of all meat and dairy commodities due to drops in producer prices across all commodities. Predicted production declines range from 35 per cent for SMP to 3 per cent for butter. As a consequence of drops in prices and a subsequent decline in production, producer returns in all meat and dairy commodities are predicted to fall. In particular, returns for dairy commodities are predicted to decrease more than 40 per cent by 2020 with the exception of butter which is predicted to fall by 12 per cent. Producer returns for meat commodities are predicted to decrease more than 30 per cent over the projection period.

Results further show that meat and dairy consumption in India is predicted to increase by 2020 due to drops in prices with the highest increase predicted for sheep meat consumption (+26 per cent), followed by WMP consumption (+23 per cent), then SMP consumption (+21 per cent). As a consequence, imports increase for most meat and dairy commodities. India is predicted to become a net importer of sheep meat, butter, WMP and SMP. It is predicted to remain a net exporter for beef and cheese – albeit for only small amounts - during the projection period. The fact that India remains a net beef exporter could be due to India's religious affiliations that imply low levels of per capita beef consumption.

Table 5.10: Scenario 5 – Impacts of full trade liberalisation in India in 2008 for China, India and New Zealand in 2020.

Measure	Commodities	China	India	New Zealand
Production quantities as percentage change to base in 2020	Beef	0.68	-12.06	0.84
	Sheep meat	1.06	-11.34	2.10
	Butter	2.94	-3.34	2.87
	Cheese	-0.21	-22.20	1.85
	WMP	0.28	-34.56	1.89
	SMP	4.85	-35.00	2.59
Producer returns as percentage change to base in 2020	Beef	2.03	-31.01	2.19
	Sheep meat	3.23	-30.33	4.30
	Butter	7.30	-12.28	7.23
	Cheese	-0.02	-39.96	2.05
	WMP	0.75	-56.55	2.37
	SMP	9.42	-55.17	7.06
Consumption quantities as percentage change to base in 2020	Beef	-0.74	18.96	-0.43
	Sheep meat	-1.45	25.62	-1.04
	Butter	-3.06	4.30	-1.75
	Cheese	0.01	15.32	-0.02
	WMP	-0.27	22.72	0.13
	SMP	-3.56	20.41	-1.69
Net trade quantities in baseline in 2020 in kilotonnes	Beef	1,049.9	847.86	473.76
	Sheep meat	545.99	56.49	510.39
	Butter	-26.71	223.15	355.97
	Cheese	8.68	0.87	387.08
	WMP	46.99	0.29	717.55
	SMP	-49.97	32.67	356.82
Net trade quantities in scenario in 2020 in kilotonnes	Beef	1,146.58	14.65	479.3
	Sheep meat	642.7	-242.44	523.91
	Butter	-16.78	-85.97	367.68
	Cheese	7.77	0.66	394.77
	WMP	53.85	-8.68	731.20
	SMP	-42.76	-83.13	367.59
GHG emissions (CO_2-equ) as percentage change to base in 2020	Dairy	-0.05	-5.76	1.81
	Beef	0.69	-12.06	0.84
	Sheep	1.06	-11.34	2.10

Note: Absolute amounts of modelling results from this scenario are attached in Appendix Table D.5.

The predicted decrease in India's meat and dairy production leads to declines in GHG emissions from livestock. The highest drop is predicted for GHG emissions from the beef sector (-12 per cent), followed by a decline in GHG emissions from sheep (-11 per cent). Dairy emissions are predicted to decrease by 6 per cent by 2020.

Fully liberalising trade in India is predicted to increase China's meat and dairy production as a result of higher prices (except for cheese which is predicted to have no change). The highest production growth is predicted for SMP (+5 per cent), then butter (+3 per cent). The increase in prices for meat and dairy commodities and subsequent production growth will lead to slight increases in producer returns across all commodities; these are ranging from 9 per cent from SMP to 1 per cent from WMP.

Results further show that free trade in India will lead to small declines in China's meat and dairy consumption due to higher prices (except for cheese consumption which remains unchanged). Consumption of SMP is predicted to drop by 4 per cent while butter consumption is expected to drop by 3 per cent by 2020. Beef and sheep meat consumption is only marginally affected. In the case of net trade, Table 5.10 shows that China is predicted to increase its beef, sheep meat, cheese and WMP exports while imports of SMP and butter are predicted to decrease. As a consequence of growth in production, GHG emissions from livestock are predicted to increase slightly in China by 2020.

For New Zealand, free trade in India would lead to slight increases in meat and dairy production by 2020, ranging from 3 per cent from butter and SMP to 1 per cent from beef due to increased producer prices. As a consequence of production growth relative to increased prices, producer returns for all meat and dairy commodities are predicted to increase by 2020. The highest increase is predicted for returns from butter (+7 per cent), then SMP (+7 per cent). In comparison, predicted increases in New Zealand producer returns are generally higher than for China with the exception of producer returns from SMP.

Results further show that New Zealand's meat and dairy consumption is expected to slightly decrease for all meat and dairy commodities in turn of higher prices with the exception of WMP consumption which remains unchanged. In terms of net trade, New Zealand is predicted to increase its meat and dairy exports across all meat and dairy commodities significantly by 2020. With regards to GHG emissions from livestock production, these are expected to increase across all livestock types in New Zealand by 2020. Increases range from 2 per cent for dairy and sheep, each, and 1 per cent for beef. In comparison, New Zealand shows slightly higher increases in GHG emissions from sheep and dairy than China in this scenario.

In summary, simulation results from full liberalisation in India are consistent with the expectations for production, consumption, producer returns, net trade and GHG emissions from meat and dairy commodities in China, India and New Zealand outlined in Section 5.3.6. As anticipated, results indicate India's producer returns across all meat and dairy commodities to fall due to declines in both producer prices and production. Further, India's GHG emissions from livestock are predicted to fall. Also, the expectations for China and New Zealand are supported in this analysis with both countries predicted to experience higher producer returns and exports from the meat and dairy sector over the projection period. However, as a consequence of increased livestock production, GHG emissions from livestock are predicted to slightly increase in China and New Zealand by 2020.

5.5 Chapter Summary

This chapter began by presenting the data that was used in this research. Then, three different dietary scenarios simulating different consumption and production patterns in India and China were developed. In addition, two trade policy scenarios simulating full trade liberalisation in India and in China were developed. Results from all five scenarios were described and discussed. Model results from the dietary scenarios indicated that changes in meat and dairy consumption and production in India and China were predicted to have an impact on production, producer returns, consumption, trade and GHG emissions from meat and dairy commodities in China, India and New Zealand. However, these impacts vary between countries, and effects depend on the level of changes in meat and dairy consumption and production. Furthermore, trade liberalisation in China was predicted to lead to higher producer returns and exports from India and New Zealand while China's producer returns and exports were predicted to decline across all meat and dairy commodities. In the case of GHG emissions from livestock these were predicted to increase for India and New Zealand while GHG emissions from the meat and dairy sector in China were predicted to fall. Finally, fully liberalising trade in India was predicted to lead to drops in India's producer returns and exports across all meat and dairy commodities and also GHG emissions from livestock were predicted to fall by 2020 as a result of drops in livestock production. For China and New Zealand, results indicated that free trade in India would lead to slightly higher producer returns and exports from meat and dairy commodities, however GHG emissions from livestock were predicted to slightly increase in both countries following increased livestock production.

The next chapter of this study will provide a summary of this research and policy implications from the modelling results. Additionally, limitations of this study and suggestions for further research will be outlined. The chapter will finish with concluding comments.

Chapter 6
Summary and conclusion

6.1 Introduction

This chapter begins with a summary of the thesis which is followed by the policy implications from this research. The limitations of the research are given with suggestions for future research, and finally concluding comments are made.

6.2 Summary

Food consumption is growing globally and is predominantly driven by a growing global population, urbanisation, and rising incomes, especially in developing countries such as China and India. The growth in food consumption in these two countries is accompanied by a change in the composition of diets away from pulses and tubers towards animal-based products such as livestock commodities. However, livestock production has been identified as contributing significantly to climate change through agricultural greenhouse gases (GHG) emissions with largest shares generated by ruminant animals (e.g., sheep and beef). These impacts are expected to grow in the future, in particular with an increased demand for meat and dairy products

New Zealand is a small open economy heavily dependent on its agricultural exports particularly from the meat and dairy sector. In recent years, New Zealand trade with developing countries such as China and India has grown. Since 2010, China is New Zealand's key export market for agricultural commodities taking almost 20 per cent of all agricultural exports with dairy commodities representing the largest share. The growth in trade flows between the two countries may be related to the Free Trade Agreement (FTA) between China and New Zealand that came into force in 2008, with tariff reductions still ongoing. The FTA will be fully implemented in 2019.

India has the potential to become an important export market for New Zealand in the future. In contrast to China, agricultural exports to India have fluctuated since 2008 reaching a peak in 2010 with exports valued at $229 million mainly from dairy. The fluctuation in New Zealand exports to India are affected by Indian trade policies which restrict imports. With current negotiations of a FTA between both countries, India has the potential to become an important export market for New Zealand.

In New Zealand, agricultural production contributes significantly to the country's GHG emissions. In 2011, almost 50 per cent of emissions were generated from agriculture with the highest proportion coming from ruminant animals and particularly from enteric fermentation. In 2010, enteric fermentation accounted for 55 per cent of all agricultural GHG emissions in New Zealand. The large share of agricultural GHG emissions in the total is uncommon for a developed country but highlights the important role agriculture plays in the New Zealand economy. However, difficulties could exist for the New Zealand economy if it has to commit to national and/or international agricultural GHG emissions targets.

Changes in consumption and production patterns in India and China as well as the implementation of new trade policies in both countries are likely to alter production and trade in other countries such as New Zealand. Consequently, this will affect global GHG emissions from the livestock sector. Thus, the aim of this research was to assess the effects of changes in meat and dairy consumption and production in India and China as well as the impacts of different trade policies in both countries on producer returns, trade and GHG emissions, particularly in New Zealand.

Trade modelling approaches have been widely used in this type of research, and there are two main modelling approaches - partial (PE) and general equilibrium (GE). GE models examine the economy as a whole and assess interactions among sectors for all commodities simultaneously while PE models examine a particular sector in the economy on a high level of commodity disaggregation and generally ignore interrelationships with other sectors. Both, PE and GE models have also been used to estimate impacts of various global issues including environmental ones.

The preferred modelling approach in this study is the PE approach because it allows for a more detailed analysis of the specific sectors under analysis. It provides insights into domestic supply, demand, trade volumes and global and domestic market prices. This research used the Lincoln Trade and Environment Model (LTEM) in order to assess the effects of increased meat and dairy consumption and production in India and China as well as various trade policies in these countries on New Zealand's trade and GHG emissions. The LTEM is able to simulate both, international trade flows of agricultural commodities and GHG emissions associated with the production of selected agricultural commodities. It is based on VORSIM, an internationally used framework, and was specifically modified to focus on New Zealand, its main trading partners and its policies. It includes disaggregation of the agricultural sector, especially for dairy, and offers flexibility and transparency in terms of adding variables, equations, policies and data. Importantly, the LTEM has the capacity to link international trade to agricultural GHG emissions to inform trade and environment policy negotiations and analysis. The model includes 21 countries or regions (including the rest of the world (ROW)) and 22 commodities.

Results from the modelling were presented for the countries selected for this study; these were India, China and New Zealand. Impacts on beef, sheep meat and four dairy commodities (namely cheese, butter, skim milk powder (SMP) and whole milk powder (WMP)) were examined.

Several studies have tried to predict future consumption, production and trade patterns for India and China using various methods. Modelling results from these studies projected varying growth rates in consumption and production of meat and dairy commodities in India and China, but only a few studies included impacts from this on agricultural GHG emissions. Also, only a few studies exist that examined impacts on agricultural supply, demand and GHG emissions from changing consumption patterns and trade policies in New Zealand. Moreover, there was a lack of consistency in projections of growth rates for India and China, reflecting the uncertainty around the growth in food consumption and production in these countries. This led to the development of three different dietary scenarios with varying levels in the consumption and production of meat and dairy commodities to assess their potential impacts on meat and dairy consumption and production, net trade and GHG emissions from livestock, particularly in New Zealand.

In Scenario 1, growth rates for meat and dairy consumption and production estimated by Rosegrant et al. (2001) were used. Growth rates from Rosegrant et al. (2001) were annualised and used for the period of 2008 and 2020. Estimated growth rates for meat and dairy consumption and production were available for India but not for China, thus growth rates from the country group *Southeast and East Asia* were used to simulate changes in China's consumption and production. Also, Rosegrant et al. (2001) did not provide a disaggregation of dairy commodities into sub-commodities. Hence, the same growth rates for milk consumption and production were applied to consumption and production of all dairy commodities of the LTEM. Overall, growth rates for consumption and production did not differ much in each country. While Indian meat and dairy consumption increased by more than 50 per cent by 2020, production growth rates were slightly smaller with increases for meat and dairy commodities of more than 40 per cent over the projected period. For China, growth rates for dairy consumption were estimated to increase by more than 60 per cent, beef consumption was expected to more than double and sheep meat consumption to increase by more than 40 per cent. China's production growth rates were similar to consumption growth for most commodities, set at 60 per cent for all dairy commodities, at 100 per cent for beef and 27 per cent for sheep meat.

In Scenario 2, growth rates provided by the OECD FAO Agricultural Outlook (2013) were used. These were available on disaggregated commodity-level for all countries and were therefore more varied than those used in Scenario 1. High growth rates were used for Indian dairy consumption with for example cheese consumption to increase 5-fold by 2020. In contrast, Indian meat consumption increased by 30 per cent over the projected period. India's growth rates for beef and sheep meat production were 64 per cent and 28 per cent, respectively. In addition, growth rates for dairy production ranged from 83 per cent of butter to 15 per cent for WMP and were therefore significantly lower than for dairy consumption. For China, growth rates for meat consumption were 20 per cent while those for dairy consumption were significantly higher with for example SMP consumption expected to more than double by 2020. In contrast, China's production growth rates for meat commodities were lower than 20 per cent and for dairy commodities lower than 40 per cent.

With increased consumption of animal products and a declining intake of cereals, roots and tubers projected for India and China, dietary patterns in both countries may be converging towards western diets. Scenario 3 assumed a partial adoption of US dietary patterns in India and China by 2020. The level of meat and dairy consumption in India and China were adjusted to reflect 20 per cent of US consumption levels. While this is an extreme scenario which is unlikely to occur in reality, it does provide some insights into the effects that significant increases in the consumption of particularly beef and some dairy commodities in India and China may have on other countries' food consumption, agricultural production and trade. For both countries, the general trend was that beef consumption increased significantly (more for India than for China). However, with an approximate 80 per cent Hindu population, it is unlikely that India reaches 20 per cent of US beef intake levels by 2020. In addition, for both countries sheep meat consumption declined as their kg/head consumption was greater than the 20 per cent of US levels (more for China than for India). With regards to dairy consumption, high growth rates were used for China across all dairy commodities while in India only WMP and SMP consumption increased and butter consumption declined. In both countries, cheese consumption was ignored in the simulations assuming that the US level in India and China was not achievable in the projection period. Also, in contrast to Scenario 1 and 2, in this scenario the change of the whole diet was simulated. Hence, consumption growth rates were applied for all 22 commodities in the LTEM as this reflected other factors such as increases in coarse grains consumption. Also, unlike in Scenario 1 and 2, in this scenario production growth rates were at baseline growth rates.

Reflecting the uncertainty around changing meat and dairy consumption and production in India and China, the three dietary scenarios included different levels of changes in production and consumption of meat and dairy commodities in order to assess particularly the impacts on New Zealand trade and GHG emissions. The main differences in the three dietary scenarios were that in Scenario 1 growth rates for consumption and production were evenly distributed across all meat and dairy commodities in both countries while in Scenario 2 growth rates for those commodities were more varied in both countries. In Scenario 3, consumption growth rates also varied and were significantly higher for beef and some dairy commodities. In addition, unlike in Scenario 1 and 2, in Scenario 3 consumption growth rates were applied to all 22 commodities in the LTEM while production rates were at baseline growth rates.

Other factors will also impact on countries' agricultural production, consumption, trade and GHG emissions. The reduction in international trade barriers may also change global production patterns, impacting the agricultural sector and trade. Thus, two different trade policy scenarios were developed to simulate the complete removal of trade barriers in China and India in order to assess the impacts on production and consumption, trade and consequently changes in GHG emissions from livestock, particularly in New Zealand.

Since its accession to the World Trade Organization (WTO) in 2001, China has opened up its borders by increasing its number of bilateral trade agreements. It has signed FTAs with New Zealand, Switzerland, Iceland, Chile, and Singapore among others and is in negotiations with several other countries. The reduction of trade barriers to China may also change the pattern of production, consumption and trade in other countries which is particularly interesting for New Zealand. Thus, full trade liberalisation in China was simulated in Scenario 4.

Also, India is currently engaged in several trade negotiations towards bilateral FTAs. This includes negotiations with the European Union, Japan, New Zealand and other South Asian countries, among others. India's further trade liberalisation may also change the pattern of production, consumption and trade in other countries. Ideally, bilateral trade relations between India and New Zealand would have been modelled to assess potential impacts of a FTA between the two countries, however the model that was used in this research does not only allow for the simulation of bilateral trade relations, thus the final scenario simulated a complete removal of trade barriers in India. While this situation is unlikely to occur in reality, it does provide some insights into the effect of India's trade policies on other countries, particularly on New Zealand.

Impacts of each scenario were shown as expected percentage changes in 2020 compared to the baseline in 2020, first for production, producer returns, consumption, net trade and GHG emissions from dairy, beef and sheep meat for China, India and New Zealand.

The results from the first three scenarios showed the differences in outcomes between various ranges of consumption and production changes in India and China. These scenarios are further referred to as dietary scenarios. The dietary scenarios included different levels of meat and dairy consumption and production in India and China which were compared to the baseline. Overall, it was shown that increased meat and dairy consumption and production in India and China were predicted to have significant effects on production and consumption, producer returns, net trade and GHG emissions in both countries by 2020 while impacts on New Zealand consumption, production, producer returns, net trade and GHG emissions were relatively moderate.

China had the highest increase in producer returns from meat and dairy commodities of all three dietary scenarios predicted in Scenario 1 with producer returns from all dairy commodities expected to grow by more than 70 per cent by 2020. The increase in producer returns was a consequence of large increases in producer prices and subsequent production growth. The predicted growth in meat and dairy production was expected because high production growth rates were used in this scenario. Similarly, consumption of meat and dairy products grew significantly in this scenario as expected from high consumption growth rates that were applied. The largest increase was shown for China's beef consumption which was predicted to almost double by 2020.

For China, it was shown that if meat and dairy consumption and production patterns were to develop as predicted by the OECD FAO Agricultural Outlook (2013) in Scenario 2 the impacts on producer returns from meat and dairy commodities were predicted to be lower than those predicted in Scenario 1. This was not surprising given the smaller growth in predicted production relative to price increases caused by the growth rates that were applied. These applied growth rates were significantly smaller for all meat and dairy commodities than those used in Scenario 1. Results from Scenario 2 showed that producer returns from dairy were predicted to increase by more than 40 per cent by 2020. In contrast, China's producer returns from meat commodities were predicted to fall over the projection period due to decreases in meat prices and a subsequent fall in production. As expected from the growth rates used, China's meat and dairy consumption increased significantly, particularly for SMP.

If China partially adopted US dietary patterns by 2020, as simulated in Scenario 3, this would lead to significant growth in China's consumption of beef and some dairy commodities, as expected. In this scenario, China's butter consumption was expected to more than quadruple by 2020 and beef consumption was expected to double. Similarly, producer prices, production and hence producer returns were estimated to increase significantly if China was to partially adopt US dietary patterns, particular from SMP and beef. Overall, these developments were align with the expectations and were consistent with the growth rates applied in this scenario.

With regards to trade, in all three dietary scenarios, China was predicted to remain a net importer of some commodities. Results from Scenario 2 suggested the largest impact on China's trade patterns of all dietary scenarios. In this scenario, China was predicted to become a large net importer of beef and dairy powders which it previously exported. In contrast, results from Scenario 1 predicted the smallest impact on China's net trade where China was still predicted to import three agricultural commodities. If China was to adopt 20 per cent of US dietary patterns by 2020 as simulated in Scenario 3, China would be depending heavily on beef and butter imports. Interestingly, under this scenario, China would significantly increase its WMP exports as a consequence of a fall in consumption while production rises.

In terms of GHG emissions from China's livestock production, simulation results from all three dietary scenarios showed that GHG emissions were predicted to increase associated with the predicted increase in production. The highest growth was predicted in Scenario 1 where GHG emissions from beef were predicted to increase by 80 per cent by 2020.

For India, the largest increase in producer returns occurred with the consumption and production patterns predicted by the OECD FAO Agricultural Outlook (2013) simulated in Scenario 2. Under this scenario, particularly producer returns from SMP, butter and beef were predicted to increase significantly by 2020 as a consequence of increased prices and subsequent production growth. This was unlike predictions for China where increases of producer returns from Scenario 1 were larger than those predicted in Scenario 2. The growth in production was consistent with and expected from the growth rates used in this scenario, especially as the applied production growth rates in this scenario were higher than those in Scenario 1, particularly for beef and some dairy commodities. As expected, meat and dairy consumption was predicted to increase significantly by 2020. The largest increase was expected for cheese consumption.

Under Scenario 1, India's producer returns from meat and dairy commodities were also predicted to increase significantly, particularly from sheep meat and cheese. This increase was a consequence of higher prices and the subsequent growth in production. The growth in meat and dairy production was expected and consistent with the growth rates used in this scenario with meat and dairy consumption growing at similar levels to the growth rates applied.

If India adopted 20 per cent of US dietary patterns as simulated in Scenario 3, producer returns from beef and SMP were predicted to increase while returns from WMP and sheep meat were predicted to decrease slightly by 2020. While the drop in sheep meat production was expected, the decrease in WMP production was an unexpected result which might be explained by the allocation of raw milk to dairy commodities (i.e., cheese, butter, WMP, SMP) in the model. This study used the allocation of raw milk to other dairy commodities that was provided by Roningen (2003). This allocation was based on historical data and might have changed over time. Furthermore, if India partially adopted US dietary patterns particularly beef consumption was predicted to increase significantly. It was predicted to more than quadruple by 2020, however this was expected from consumption growth rates applied and as mentioned above, it is highly unlikely that India will ever reach 20 per cent of US beef intake levels due to religious reasons.

For India, an interesting result from the three dietary scenarios was that when the production growth rates were more evenly distributed as in Scenario 1, the predicted production growth from the modelling occurred as expected and was consistent with the growth rates applied. However, when more varied production growth rates for disaggregated commodities were applied as in Scenario 2 and Scenario 3 then particularly the development of WMP production was much lower or even inconsistent with growth rates used in the modelling. Again, this might be due the allocation of raw milk to dairy commodities within the LTEM.

With regards to India’s net trade, modelling results of the three dietary scenarios showed that if increases in meat and dairy consumption and production will occur as predicted in Scenario 1, India will still remain a net exporter of all commodities. However, if changes in India’s meat and dairy consumption and production followed growth levels estimated by the OECD FAO Agricultural Outlook (2013) as simulated in Scenario 2, India was predicted to become a net importer of WMP that it previously exported. Model results showed the largest impact on India’s trade in the event of India adopting 20 per cent of US consumption patterns by 2020 as simulated in Scenario 3. In this case, India was predicted to become a net importer of three commodities, these were WMP, SMP and beef.

With regards to GHG emissions from livestock, model results for the three dietary scenarios predicted the highest increase for Scenario 2, particularly from beef. These were predicted to increase by 50 per cent by 2020. However, this was expected from the significant increase in livestock production that was predicted in this scenario.

Overall for New Zealand, changes in meat and dairy consumption and production in India and China were predicted to have mixed effects on producer returns. Table 6.1 summarises the main results for New Zealand producer returns and GHG emissions from livestock from the three dietary scenarios. It can be seen that the largest increase in New Zealand producer returns were predicted if China and India partially adopted US dietary patterns as simulated in Scenario 3. In particular, producer returns from beef and SMP were predicted to increase by more than 30 per cent by 2020, each. However, interestingly, in the same scenario, returns from WMP were predicted to fall as a consequence of drops in prices and a subsequent decline in domestic production.

Impacts on New Zealand producer returns were more varied if China and India increased meat and dairy consumption and production by relatively large growth rates that are evenly distributed across all meat and dairy commodities as simulated in Scenario 1. In this scenario, an important result was that producer returns from dairy commodities were predicted to fall as a consequence of decreases in global dairy prices and subsequent falls in production. Producer returns for WMP and butter were predicted to fall by 9 per cent, each. However, in the same scenario an increase of 15 per cent in returns from sheep meat were predicted following increased production relative to higher prices. For New Zealand, this was the highest predicted increase in returns from sheep meat of all dietary scenarios.

If China and India’s growth rates for meat and dairy consumption and production followed the OECD FAO Agricultural Outlook (2013) projections as simulated in Scenario 2, New Zealand producer returns for those commodities were predicted to increase moderately by 2020 with the largest increase predicted for returns from SMP. However, producer returns from butter were predicted to decline as a consequence of drops in prices and subsequent declines in production.

Table 6.1: Key results for producer returns from meat and dairy commodities and GHG emissions from livestock in New Zealand in 2020 from three dietary scenarios.

Scenario	Producer returns as percentage change to base in 2020						GHG emissions as percentage change to base in 2020		
	Beef	Sheep meat	But-ter	Cheese	WMP	SMP	Beef	Sheep	Dairy
High growth rates (Rosegrant)	1.4	15.4	-9.0	-2.2	-9.3	0.9	-0.0	7.9	-2.5
Mixed growth rates (OECD FAO 2013)	0.7	8.6	-11.2	1.1	6.0	9.8	0.0	4.4	0.7
Partial adoption of US diet	38.0	-2.6	7.	-(1)	-5.1	30.5	14.1	-2.4	2.5

Note:
(1) The impact on cheese was ignored in this scenario.

With regards to net trade, New Zealand exports of meat and dairy commodities would rise significantly if India and China were to adopt 20 per cent of US dietary patterns with the highest increases predicted for beef. This was expected due to increased global demand for beef. In Scenario 2, only small increases in meat and dairy exports were predicted. Interestingly, in Scenario 1 slight decreases in dairy exports were predicted as a consequence of drops in dairy production while domestic consumption increased.

Results showed that dietary changes in India and China will only slightly affect GHG emissions from New Zealand's dairy and meat sector. Under Scenario 1 and 2 particularly GHG emissions from sheep were predicted to increase by 2020 (see Table 6.1). The most significant result concerns the associated effect of China and India's partial adoption of US dietary patterns which showed a significant increase in GHG emissions particularly from beef as a consequence of increased production. This scenario predicted the highest increase in GHG emissions compared to all dietary scenarios.

The last two scenarios in this study were trade policy scenarios. While Scenario 4 assumed full trade liberalisation in China in 2008, Scenario 5 assumed full trade liberalisation in India in 2008. From these trade policy changes, impacts on production, producer returns, consumption, and net trade from meat and dairy commodities as well as GHG emissions from livestock were assessed for China, India and New Zealand.

If China removes its trade barriers completely significant declines for China's producer returns across all meat and dairy commodities were predicted as a consequence of falls in producer prices and subsequent drops in production. Due to these drops in prices, meat and dairy consumption in China was expected to increase. Net trade decreased correspondingly and under full trade liberalisation China was to be a net importer for all meat and dairy commodities by 2020. However, the decline in meat and dairy production would lead to decreases in GHG emissions from both sectors by 2020.

Under China's full trade liberalisation, India was predicted to have slightly increased producer returns across all meat and dairy sectors resulting from increases in production relative to higher producer prices. Due to higher prices, consumption decreased for all commodities. Net trade increased across all the commodities with India exporting more. As a consequence of increased production, GHG emissions from livestock in India were predicted to grow under free trade in China.

Table 6.2 summarises the main results for New Zealand producer returns and GHG emissions from livestock from both trade policy scenarios. Under China's trade liberalisation, New Zealand was predicted to experience slightly increased producer returns from the meat and dairy sectors, particularly from sheep meat and WMP. This was due to increased production caused by higher prices. New Zealand's consumption of meat and dairy products was predicted to decline slightly by 2020 due to higher prices. As a consequence, New Zealand was predicted to increase its exports across all meat and dairy commodities. The associated effect of growth in livestock production was a predicted increase in GHG emissions, particularly from sheep.

Table 6.2: Key results for producer returns from meat and dairy commodities and GHG emissions from livestock in New Zealand in 2020 from trade policy scenarios.

Scenario	Producer returns as percentage change to base in 2020						GHG emissions as percentage change to base in 2020		
	Beef	Sheep meat	Butter	Cheese	WMP	SMP	Beef	Sheep	Dairy
China full trade liberalisation	3.2	8.4	2.6	2.6	7.2	2.2	1.1	4.2	1.7
India full trade liberalisation	2.2	4.3	7.2	2.0	2.4	7.1	0.8	2.1	1.8

In the case of India's full trade liberalisation, modelling results indicated that India's production, producer returns and exports would decrease significantly by 2020. While meat and dairy production was predicted to decrease, India's meat and dairy consumption would increase by 2020 under full trade liberalisation. Due to the fact that India was a net exporter of all meat and dairy commodities in the baseline, impacts on India's net trade were relatively moderate with India still remaining a net exporter of beef and cheese. However, with liberalising its trade, India would become a net importer of sheep meat, butter and dairy powders by 2020. Results showed that India's GHG emissions from the livestock sector were predicted to drop due to declines in livestock production.

Under the Indian free trade scenario, China's producers were predicted to have increased producer returns across all commodities generated by higher prices and subsequent growth in production. However, a consequence of these increased prices was a fall in consumption of meat and dairy products. Net trade increased correspondingly with predicted increases in exports and a reduction in imports. However, GHG emissions from China's livestock sector were predicted to increase slightly by 2020 as a consequence of production growth.

Under free trade in India, New Zealand producer returns were predicted to increase particularly returns from dairy commodities. This was a consequence of increased production relative to higher dairy prices (see Table 6.2). Results further suggested that free trade in India would significantly affect New Zealand's net trade with large increases predicted for exports from all commodities. However, following increased meat and dairy production in New Zealand, GHG emissions from livestock were predicted to increase, particularly from sheep and dairy.

6.3 Policy implications for New Zealand

This study estimated and discussed possible changes to production, prices, producer returns, consumption and net trade in the meat and dairy sector in New Zealand, and their GHG emissions from changing consumption and production patterns of meat and dairy commodities in India and China. Furthermore, the impacts of trade liberalisation in India and China on the meat and dairy sector in New Zealand were assessed.

Overall, the simulation results suggest that changing dietary patterns in India and China will lead to higher producer returns from meat and some dairy commodities in New Zealand as a consequence of increased world prices and domestic production. This is particularly the case if China and India partially adopted US consumption patterns. However, when India and China significantly increased meat and dairy consumption and production simultaneously as simulated in Scenario 1, it was shown that producer returns, particularly from dairy could decrease by 2020 due to drops in production relative to international prices. These potential developments of declines in dairy returns could have implications for dairy producers and exporters from New Zealand in the future, and should be taken into account when forecasts for the dairy sector are developed and export or investment strategies are discussed.

This research also predicted that growth in meat and dairy consumption and production in India and China could lead to increased GHG emissions from the New Zealand livestock sector. Although increases in GHG emissions were only small, they were still significant, particularly from sheep. This would be of particular importance if New Zealand were to set agricultural GHG emissions targets, for example within the New Zealand Emissions Trading Scheme (ETS) or if the government considered signing the second commitment period of Kyoto which applies to emissions between 2013 and 2020. Therefore, it would be important for New Zealand to ensure, that in remaining a key trading partner for those countries, it can still manage and/or minimise agricultural GHG emissions.

As shown in Chapter 1, New Zealand exports increased significantly between 2008 and 2013. In particular, large growth in dairy exports to China were recorded in that period. In order to examine if the growth in New Zealand trade was captured by the LTEM, actual trade data from 2013 (which was the latest year available from Statistics New Zealand) was compared to trade projections for 2013 from the baseline. The comparison showed that modelling projections of total New Zealand meat exports were overestimated while total dairy exports were underestimated by the LTEM. This underestimation of dairy exports could be due to an unexpected significant increase in global demand for dairy (as a consequence of consumption growth exceeding production growth) which New Zealand had the capacity to meet. Another reason for the growth in dairy exports particularly to China may be the signing of the FTA in 2008 between the two countries. Impacts of this were not captured by the modelling as the model's base year was 2008, however changes in tariffs for dairy products are still ongoing and will be fully removed by 2019. However, it could be that the FTA has enhanced relationships between the two countries, and thus increased the trade flows of dairy commodities. This is interesting and may mean that in the future New Zealand’s dairy exports are likely to grow further, particularly if tariff elimination for dairy commodities is completed in 2019. In addition, this study gave an insight into impacts from full trade liberalisation in China on New Zealand trade (Scenario 4) and predicted an increase of New Zealand dairy exports by 2020. Also here, the comparison of the modelling results of total New Zealand dairy exports from this scenario with actual trade data in 2013 showed that predicted dairy exports were still underestimated. These results imply that if China opens up its economy to all other countries, New Zealand dairy exports could grow further.

Full trade liberalisation in India was predicted to lead to increased producer returns and exports particularly for dairy commodities from New Zealand as a consequence of higher producer prices and increased market access. Increases in producer returns could be as high as US$553 million by 2020. This is an important result as New Zealand has continuous negotiations towards a FTA with India. However, besides the predicted gains for New Zealand producers and exporters in the meat and dairy sector from this, India's complete removal of trade barriers would generate an increase in GHG emissions from livestock sector in New Zealand which should be taken into account when further negotiation conditions of the FTA.

6.4 Limitations

Limitations of this research broadly relate to data availability and accuracy, the modelling framework and the specific model used in this research, the LTEM.

As with many types of research, the availability and accuracy of data was a constraint. General data from a single source was difficult to obtain, thus several databases had to be used for the model data on prices, consumption, production, trade barriers, population and GDP. However, in order to maintain consistency most data was obtained from global databases (World Bank, FAO and OECD) rather than from national databases. In addition, the use of a more recent year for the baseline may have provided more accuracy accounting for recent changes, especially for China.

There was a lack of recent data on elasticities. Ideally, elasticities would have been estimated using prices, quantities and income for each country. However, this is complex and is often not feasible due to lack of data, and this would have involved a considerable amount of further research and was thus considered to be beyond the scope of this study.

For the development of different dietary scenarios, growth rates for different consumption and production patterns for the projection period 2008 to 2020 for China and India across all meat and dairy commodities were difficult to obtain. Only one study was found that provided growth rates for all countries and all commodities while other studies only provided growth rates for the countries but then not for the level of commodity disaggregation required by the LTEM or growth rates were available for one country and not for the other. Thus, several assumptions had to be made particularly around the growth rates for meat and dairy production in India and China used in Scenario 1.

There are also limitations related to the PE modelling framework used in this research (see Section 4.2). This refers predominantly to the aspect that PE models only model one part of the economy and assumes that the impact of that sector on the rest of the economy are either non-existent or very small. However, this study focused on the agricultural sector as it is such an important industry for New Zealand's economy, as well as the sector's effects on GHG emissions, and the depth of analysis undertaken would not have been possible if more sectors had been included in this study.

Another limitation relates specifically to the PE model that was used in this research. The LTEM is a non-bilateral model emphasising the net trade of commodities in each region, thus it lacks the ability to model trade flows between regions to allow for differentiated markets and bilateral trade flows. Ideally, bilateral trade relations between India and New Zealand would be have been modelled in this research in order to assess the effects of a potential FTA between the two countries. However, the model did not capture this, hence a simulation of full trade liberalisation in India was assessed instead. Also, in the LTEM products are considered homogeneous with regards to physical product characteristics, to country of origin and destination in the LTEM implies that it is not possible to differentiate between varying qualities of the same product. Producers may decide to focus on certain quality attributes rather than simply increasing production in response to price, and this model did not capture this.

Also, in the LTEM, emissions of GHG are calculated based on animal numbers which are the main determinants for generating methane (CH_4) while nitrous oxide (N_20) is predominantly generated by nitrogen from the use of synthetic nitrogen fertiliser and manure as well as soil processes. However, although livestock are the major sources of agricultural GHG emissions, other factors that generate GHG emissions such as changes in land use were ignored in this research. Thus, results could be an underestimation of GHG emissions. Another limitation in the model is that emissions per animal are assumed constant. Hence, mitigation effects such as the adoption of new technologies and farm practices that may reduce emissions per animal were not taken into account in the calculation of GHG emissions from livestock.

6.5 Suggestions for further research

One area for further research concerns the data in the LTEM. Future research could include an update of the model’s dataset on producer and consumer prices, production and consumption quantities, beginning and ending stocks, producer and consumer subsidies and taxes, tariffs and quotas, population data and GDP. In addition, parameter estimates such as elasticities and growth rates could be revised in future research as it was difficult to obtain recent parameters for all countries and commodities from one source. Likewise, the use of a more recent year for the baseline projections would have benefited this studies’ reliability by providing a more realistic picture on developments in the meat and dairy sector, especially in China.

While some sensitivity analysis on consumption and production growth rates for China and India has been carried out in this research, future research could involve conducting further sensitivity analysis around these to further support the robustness of study results.

An area of future research concerns the growth in trade flows for New Zealand simulated by the model. As mentioned in the policy implications in Section 6.3, a comparison of New Zealand export projections estimated by the LTEM with actual trade data from Statistics New Zealand indicated that total dairy exports from New Zealand were underestimated by the model for 2013. Accordingly trade projections would also be an underestimate for the year 2020. Thus, future research could include the update of growth rates of consumption and production for New Zealand to provide an improved picture of New Zealand's trade flows in the future.

With regards to elasticities included in the LTEM, future research could include these being estimated econometrically. As mentioned above, this would require further data collection. Also, as mentioned above (see Section 4.4.1), literature has shown that both demand and supply elasticities may change over time as income elasticities depend on the income level and cross-price elasticities of demand (or supply) depend on the food budget shares (or crop area shares). Thus, the revision of elasticities during the projection period would improve the accuracy of simulations.

From the modelling of the different consumption and production changes in India and China some unexpected results were found which could be further examined in future research. For India, an interesting result from the three dietary scenarios was that, when more varied consumption (and production) growth rates for the dairy commodities were applied as conducted in Scenario 3, then some inconsistency to the applied growth rates was predicted for the development of India's WMP production. As mentioned before, this might be explained by the allocation of raw milk to the traded other dairy commodities (namely cheese, butter, WMP, SMP) in the model. This study used the allocation of raw milk to other dairy commodities that was provided by Roningen (2003). This allocation is based on historical data and has probably changed over time, thus in future research the allocation of raw milk to dairy commodities could be further examined and different allocation combinations could be tested. For New Zealand, an unexpected result was the drop in dairy production, particularly of WMP as simulated in Scenario 1, future research could include the analysis of other commodities of the LTEM to assess how the production of those is affected in order to assess if there are other sectors that could compensate for the reduction in dairy production.

Future research could include to allocate this studies' projections of total net trade between regions to allow for the assessment of bilateral trade flows. This would enable for example the assessment of potential effects of a FTA between India and New Zealand. It would also allow for the assessment of countries other than New Zealand that increased exports to China after it fully liberalised trade as simulated in Scenario 4. This could be of importance for New Zealand in order to assess which countries will increase their exports of similar agricultural commodities to New Zealand to meet China's demand.

A subject for further research could be the development of a dietary scenario that includes consumption and production growth rates for all agricultural commodities estimated by the OECD FAO Agricultural Outlook (2013). The OECD FAO Agricultural Outlook (2013) provides growth rates for agricultural commodities on disaggregated commodity-level for all countries and for the whole projection period. In Scenario 2, growth rates for China and India's meat and dairy consumption and production were used to assess the impacts of these on New Zealand's meat and dairy sector. Thus, the extension of this dietary scenario to other commodities will provide a picture of complete dietary change and will assess the effects of this on New Zealand trade and GHG emissions from livestock

Sections 2.3 and 2.4 of this study showed that India's and China's consumption and production of beef, sheep meat, poultry and pork commodities were projected to increase significantly by 2020. In this study, the analysis included two meat commodities, namely beef and sheep meat, and therefore did not include other meat commodities such as poultry and pork. However, the model that was used in this research simulates effects for all four meat commodities for each scenario. Hence, future research could include the analysis of all meat commodities. This would provide an improved picture of developments in the meat sector in India, China and New Zealand.

In accordance to the above, another area of future research concerns this study's analysis relative to the LTEM's modelling capacity. As mentioned above, the LTEM includes 21 countries/regions and 22 commodities, for which simulations of economic variables for the meat and dairy sector and GHG emissions from the livestock were predicted. The scope of this study concerned the analysis of just three countries and only six of the model's commodities. Hence, future research could involve the analysis of all 22 commodities including their GHG emissions to assess the effects of dietary changes of all food products in developing countries. These results could be then combined with a GE model to capture further dimensions in order to be more representative of the reality. This extension would show impacts on other sectors in the economy and on the labour market in combination with the detailed results from the agricultural sector from the LTEM. However, this would require input – output data and pre-estimated elasticity parameters which might be difficult to retrieve, particularly for developing countries.

Another area of future research suggests the inclusion of the growth rates of meat and dairy consumption and production of other major developing countries or regions such as countries from the Sub-Saharan continent or the Middle East in the model which would provide additional insights into potentially important export markets for New Zealand. Literature (e.g., FAO, 2009) has shown that the majority of the increase in meat and dairy consumption is predicted to be in developing countries; with largest numerical increases in East and South Asia (among others) but a doubling – albeit from a low level – is predicted for Sub-Saharan Africa due to urbanisation and rising incomes. This would require considerable amount of data collection which is not always available particularly for developing countries. Another trend which could be subject to future research is the constant increase in meat and dairy production in the US and EU (and Brazil), this might have an effect on New Zealand's producers and exports in the future. Thus, in future research, scenarios could be developed that simulated different production growth scenarios for the meat and dairy sector in the EU and US (and Brazil) to assess the impacts of those on New Zealand's meat and dairy sector.

6.6 Concluding comments

In China and India dietary patterns are changing away from cereals, tubers and pulses towards meat and dairy products and subsequently converging towards western diets. While this development can lead to higher producer returns and exports for meat and dairy commodities in New Zealand, in some cases drops in producer returns and exports for dairy commodities might occur. This is particularly the case, if these countries are able to meet domestic demand themselves. In contrast, changes in trade policies in terms of full trade liberalisation in China and India have overall positive effects for New Zealand's producers and exporters. This shows the importance of these markets to the New Zealand economy. However, the associated effect from increased meat and dairy production in New Zealand from changing diets and international trade policies is an increase in GHG emissions from livestock, and challenges are faced if New Zealand has to commit to national and/or international agricultural GHG emissions targets.

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Appendix A
Changes in food consumption

Change in food consumption[(1)] by category and region between 1961 and 2009, in per cent.

Food category	**World**	**Africa**	**North America**	**Central America**	**South America**	**Asia**	**Europe**	**Australia & NZ**	**China**	**India**
Cereals	150%	304%	106%	210%	199%	207%	-11%	92%	236%	174%
Fruits	324%	370%	137%	402%	226%	621%	111%	186%	3324%	409%
Oilcrops	218%	297%	121%	239%	695%	192%	277%	195%	170%	242%
Pulses and roots	70%	320%	73%	232%	81%	60%	-16%	180%	10%	236%
Vegetable oils	436%	492%	295%	502%	701%	777%	156%	1,433%	1,372%	467%
Animal Fats	83%	205%	-9%	462%	161%	659%	10%	5%	1,635%	609%
Eggs	327%	564%	31%	1,173%	457%	1,089%	60%	4%	1,716%	1,813%
Meat	298%	339%	120%	627%	382%	1,313%	84%	115%	3,001%	215%
Milk	153%	359%	56%	426%	313%	502%	46%	66%	2,351%	399%
Total	**165%**	**328%**	**87%**	**332%**	**225%**	**259%**	**27%**	**107%**	**260%**	**251%**

Note: (1) This is food availability for human consumption.

Source: FAOSTAT (2012a).

Appendix B
Changes in food production

Change in food production by category and region between 1961 and 2009, in per cent.

Food category	**World**	**Africa**	**North America**	**Central America**	**South America**	**Asia**	**Europe**	**Australia & NZ**	**China**	**India**
Cereals	182%	229%	159%	258%	248%	282%	77%	275%	359%	194%
Fruits	249%	247%	61%	396%	271%	622%	25%	187%	3,451%	426%
Oilcrops	367%	158%	343%	-7%	1,945%	309%	255%	5784%	447%	287%
Pulses and roots	61%	401%	90%	214%	61%	115%	-43%	384%	60%	215%
Vegetable oils	676%	275%	288%	433%	1264%	1,379%	295%	982%	1,613%	274%
Animal fats	96%	114%	59%	261%	221%	606%	25%	76%	2,100%	546%
Eggs	351%	563%	45%	1,219%	550%	1,112%	69%	15%	1,723%	1,855%
Meat	303%	308%	156%	479%	469%	1,251%	83%	149%	2,962%	251%
Milk	104%	252%	44%	331%	327%	501%	10%	125%	2,089%	444%
Total	**164%**	**287%**	**141%**	**291%**	**309%**	**310%**	**28%**	**200%**	**333%**	**269%**

Source: FAOSTAT (2012a).

Appendix C
LTEM emissions factors

C.1 - Emission factors for methane from enteric fermentation for China, India and New Zealand, (kg CH_4/head), 2010

Type	New Zealand	China	India
Dairy	60	272	58
Beef	1.5	188	27
Sheep	8	20	5

Source: FAOSTAT (2013).

C.2 - Emission factors for methane and nitrous oxide from manure management for China, India and New Zealand, 2010

Type	Kg CH_4/head			Kg N_2O/head		
	New Zealand	China	India	New Zealand	China	India
Dairy	23	9	5	0.1	0.39	0.017
Beef	1	1	2	0.2	0.68	0.02
Sheep	0.19	0.01	0.15	0	0.03	0.03

Source: FAOSTAT (2013).

Appendix D
Modelling results

D.1 - Scenario 1 - Impacts of increases in meat and dairy consumption and production in India and China for China, India and New Zealand in 2008 and 2020 (Rosegrant)

Measure	Commodities	China		India		New Zealand	
		2008	2020	2008	2020	2008	2020
Consumption in kilotonnes	Beef	6,081	12,353	2,280	3,572	121	123
	Sheep meat	3,471	4,801	761	1,121	86	85
	Butter	173	297	3827	6207	31	33
	Cheese	402	646	0	0	28	28
	WMP	1186	1940	15	24	4	4
	SMP	112	169	183	378	35	35
Production in kilotonnes	Beef	6,133	13,149	2,908	4,161	636	596
	Sheep meat	3,470	4670	783	1,190	597	645
	Butter	142	276	3830	6,899	349	377
	Cheese	376	778	1	2	369	405
	WMP	1,200	2282	15	26	643	696
	SMP	60	129	211	397	351	383
Producer returns in US$m	Beef	14,025	28,726	8,605	11,763	951	852
	Sheep meat	8,209	11,108	1,935	2,958	1,240	1,347
	Butter	257	435	7,151	11,225	1,093	1,030
	Cheese	1,127	2,252	2	4	1,571	1,668
	WMP	1,746	2,931	32	48	2,557	2,445
	SMP	75	157	428	784	1,352	1,440
Net trade in kilotonnes	Beef	52	-158	628	1,842	515	473
	Sheep meat	0	130	22	75	511	539
	Butter	-31	-119	3	1,113	317	353
	Cheese	-26	-37	1	1	341	390
	WMP	14	-110	0	-35	639	728
	SMP	-52	-205	28	85	316	360
GHG emissions (CO_2-equ.) in kilotonnes	Dairy	74,581	100,088	53824	73,502	7,721	8,531
	Beef	441979	947552	99512	142391	620	581
	Sheep	73,077	98,339	8,418	12,796	5,863	6,334

D.2 - Scenario 2 - Impacts of changes in meat and dairy consumption and production in India and China for China, India and New Zealand in 2008 and 2020 (OECD FAO Agricultural Outlook)

Measure	Commodities	China		India		New Zealand	
		2008	2020	2008	2020	2008	2020
Consumption in kilotonnes	Beef	6,081	7,392	2,280	2,968	121	123
	Sheep meat	3,471	3,804	761	981	86	86
	Butter	173	302	3,827	7,454	31	34
	Cheese	402	637	0	0	28	28
	WMP	1,186	1905	15	57	4	4
	SMP	112	288	183	402	35	35
Production in kilotonnes	Beef	6,133	7,234	2,908	4,810	636	597
	Sheep meat	3,470	3,934	783	1,056	597	625
	Butter	142	183	3,830	8,567	349	388
	Cheese	376	600	1	1	369	419
	WMP	1200	1795	15	22	643	731
	SMP	60	83	211	487	351	395
Producer returns in US$m	Beef	14,025	15,684	8,605	13,496	951	846
	Sheep meat	8,209	9,098	1,935	2,552	1,240	1,267
	Butter	257	273	7,151	13,220	1,093	1,005
	Cheese	1,127	1,740	2	3	1,571	1,724
	WMP	1,746	2,565	32	46	2,557	2,857
	SMP	75	106	428	1,015	1,352	1,567
Net trade in kilotonnes	Beef	52	-158	628	1,842	515	473
	Sheep meat	0	130	22	75	511	539
	Butter	-31	-119	3	1,113	317	353
	Cheese	-26	-37	1	1	341	390
	WMP	14	-110	0	-35	639	728
	SMP	-52	-205	28	85	316	360
GHG emissions (CO_2-equ.) in kilotonnes	Dairy	74,581	92,771	53,824	73,621	7,721	8,808
	Beef	441,979	521,267	99,512	164,602	620	581
	Sheep	73,077	82,847	8,418	11,356	5,863	6,130

D.3 - Scenario 3 - Impacts of a partial adoption of US dietary patterns in China and India on the meat and dairy sector in China, India and New Zealand in 2008 and 2020

Measure	Commodities	China		India		New Zealand	
		2008	2020	2008	2020	2008	2020
Consumption in kilotonnes	Beef	6,081	14,383	2,280	10,114	121	110
	Sheep meat	3,471	3,201	761	814	86	91
	Butter	173	768	3,827	3,752	31	32
	WMP	1,186	1,150	15	36	4	4
	SMP	112	415	183	446	35	33
Production in kilotonnes	Beef	6,133	8,463	2,908	3,548	636	680
	Sheep meat	3,470	4,053	783	839	597	584
	Butter	142	196	3,830	4,247	349	408
	WMP	1,200	1,477	15	15	643	732
	SMP	60	99	211	271	351	413
Producer returns in US$m	Beef	14,025	22,072	8,605	11,973	951	1,160
	Sheep meat	8,209	8,997	1,935	1,948	1,240	1,137
	Butter	257	337	7,151	7,517	1,093	1,214
	WMP	1,746	1,888	32	27	2,557	2,557
	SMP	75	144	428	644	1,352	1,863
Net trade in kilotonnes	Beef	52	-5,920	628	-6,566	515	570
	Sheep meat	0	851	22	26	511	493
	Butter	-31	-572	3	494	317	376
	WMP	14	328	0	-21	639	728
	SMP	-52	-316	28	-176	316	380
GHG emissions (CO_2-equ.) in kilotonnes	Dairy	74,581	104,406	53,824	59,104	7,721	8,971
	Beef	441,979	609,883	99,512	121,404	620	663
	Sheep	73,077	85,339	8,418	9,028	5,863	5,732

D.4 - Scenario 4 - Impacts of full trade liberalisation in China for India, China and New Zealand in 2008 and 2020

Measure	Commodities	China		India		New Zealand	
		2008	2020	2008	2020	2008	2020
Consumption in kilotonnes	Beef	6,081	6,855	2,280	2,328	121	123
	Sheep meat	3,471	3,864	761	773	86	86
	Butter	173	196	3,827	3,937	31	32
	Cheese	402	447	0	0	28	28
	WMP	1,186	1,282	15	15	4	4
	SMP	112	123	183	188	35	36
Production in kilotonnes	Beef	6,133	6,612	2,908	3,232	636	603
	Sheep meat	3,470	3,995	783	866	597	624
	Butter	142	132	3,830	4,162	349	396
	Cheese	376	336	1	1	369	423
	WMP	1,200	1,130	15	16	643	739
	SMP	60	56	211	222	351	400
Producer Returns in US$m	Beef	14,025	12,256	8,605	9,197	951	867
	Sheep meat	8,209	8,059	1,935	2,093	1,240	1,265
	Butter	257	191	7151	7,267	1,093	1,161
	Cheese	1,127	817	2	2	1,571	1,748
	WMP	1,746	1469	32	34	2,557	2,889
	SMP	75	61	428	425	1,352	1,458
Net trade in kilotonnes	Beef	52	-243	628	904	515	480
	Sheep meat	0	132	22	93	511	537
	Butter	-31	-64	3	225	317	363
	Cheese	-26	-111	1	1	341	395
	WMP	14	-152	0	1	639	735
	SMP	-52	-66	28	34	316	364
GHG emissions (CO_2-equ.) in kilotonnes	Dairy	74,581	77,027	53,824	59,831	7,721	8,900
	Beef	441,979	476,450	99,512	110,587	620	588
	Sheep	73,077	84,141	8,418	9,317	5,863	6,120

D.5 - Scenario 5 - Impacts of full trade liberalisation in India for China, India and New Zealand in 2008 and 2020

Measure	Commodities	China		India		New Zealand	
		2008	2020	2008	2020	2008	2020
Consumption in kilotonnes	Beef	6,081	6,238	2,280	2,803	121	122
	Sheep meat	3,471	3,568	761	994	86	87
	Butter	173	173	3,827	4,118	31	32
	Cheese	402	404	0	0	28	28
	WMP	1,186	1,217	15	19	4	4
	SMP	112	111	183	227	35	35
Production in kilotonnes	Beef	6,133	7,384	2,908	2,817	636	601
	Sheep meat	3,470	4,211	783	752	597	611
	Butter	142	157	3,830	4,032	349	400
	Cheese	376	412	1	1	369	423
	WMP	1,200	1,271	15	10	643	735
	SMP	60	68	211	144	351	403
Producer returns in US$m	Beef	14,025	16,126	8,605	6,164	951	859
	Sheep meat	8,209	9,561	1,935	1,373	1,240	1,217
	Butter	257	274	7,151	6,343	1,093	1,214
	Cheese	1,127	1,190	2	1	1571	1740
	WMP	1,746	1,745	32	14	2557	2759
	SMP	75	83	428	189	1352	1528
Net trade in kilotonnes	Beef	52	1147	628	15	515	479
	Sheep meat	0	643	22	-242	511	524
	Butter	-31	-17	3	-86	317	368
	Cheese	-26	8	1	1	341	395
	WMP	14	54	0	-9	639	731
	SMP	-52	-43	28	-83	316	368
GHG emissions (CO_2-equ.) in kilotonnes	Dairy	74,581	82,404	53,824	56,381	7,721	8,909
	Beef	441,976	532,139	99,512	96,407	620	586
	Sheep	73,077	88,671	8,418	8,086	5,863	5,995