Demographic Change and Demand for Food in Australia*

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ABSTRACT

The analysis of global population forecasts of the past 30 years by the US National Academy of Sciences confirms that errors have been considerable and that population forecasts have generally been upward-biased. Recent stochastic population projections also yield wide error bounds. We discuss the demographic implications of one set of stochastic projections and adapt a standard global economic model to estimate the implications of population forecast errors for the performance of the global economy and its agricultural sectors. The model is *GTAP-Dynamic*, a recursively dynamic, applied general equilibrium model of the world economy widely used in the analysis of trade policy. The results indicate that the growth rate of population in the rest of the world is important for Australia's economic health. If the global population grows more slowly than the median forecast suggests, Australia's manufacturing and services sectors would gain at the expense of commodities. The impact on individual agricultural sectors also depends on which region the slower population growth occurs.

1. INTRODUCTION

Final demand for all goods and services depends classically on preferences, the level of aggregate income, the distribution of that income across households with differing preferences, the age composition of those households and, finally, on relative product and service prices. Our interest is in the particular dependence of the pattern of final demand on the size and age structure of consuming populations. On a global scale this is complicated by the diversity of growth and decline in populations across regions.

The major demographic phenomenon that the world is experiencing is that the rate of growth of the global population is slowing quite quickly. The populations of nearly all countries are also aging—some very rapidly. Indeed, the populations of some countries will begin to decline within a few years. Long-term global population projections of only a few years ago, including those done by the United Nation's Population Division, have been revised downwards and it appears that even present projections are too high (Duncan and Wilson, 2004).

These demographic changes have implications for many facets of economic life, including work force structure, savings and investment, retirement incomes, health expenditures, and consumption of goods and services. The changes are even likely to

have implications for the quantity of food consumed, the types of food consumed, and the ways in which food is consumed (Blandford, 1984; Duncan and Meng, 2004).

How is the slowing of population growth and the aging of the global population likely to affect the demand for food (both domestic and export demand) in Australia? Market expectations for Australian food exporters have been based on expectations of continuing large increases in populations in most of the importing countries. These expectations about population increases need reappraisal. In this paper we focus on the size and global distribution of the world's population and the potential impact of population forecast uncertainties on projected economic behaviour, and thereby on projections of the composition of demand facing Australian commodity exporters.

A brief review of the past global population projections, including those made by the United Nations (UN) Population Division, is offered in Section 2. That section then briefly introduces some new probabilistic forecast methods and results for the global and regional population in the next few decades. These results provide both the median and the uncertainty intervals of the future population size, which are the input of our simulation exercises later. The possible impacts of different population size on the economy are briefly discussed in this section as well. Section 3 is an overview of the economic model used to explore the question of our interest. In Section 4, we discuss our approach of applying this model. Projection results with high and low (versus the medium of the forecast) population growth in developing and industrial countries are discussed in Section 5. Section 6 offers conclusions and the plan for further studies.

2. GLOBAL POPUALTION PROJECTIONS

In the policy sciences analyses often depend on forecasts of population growth and composition. Such forecasts are commonly seen as "firm" relative to expectations about peoples' economic or social behaviour. Yet there are numerous sources of demographic uncertainty, particularly fertility, but also mortality, migration and the sex ratio at birth, some of which have not been well understood by researchers. In most countries, infant mortality fell through the course of the last century and adult life expectancy increased. Yet, most strikingly, there have been sharp declines in fertility, first in developed countries and recently in many developing countries. Before this century is half over,

populations in Japan and some European countries are likely to be smaller than they were in 1990, with these declines in total populations being preceded by declines in corresponding number of people of working age.[1]

2.1 A brief review of the past population projections

All the past population projections since the World War Two have been based on the so called 'cohort-component' projection originated in the 1930s (De Gans 1999). The results of these projections are essentially driven by the assumptions of the key variables such as fertility, motility. However, they have not taken into account of the uncertainty of these variables (Wilson, 2002). These projections include those made by the Population Division of the United Nations, which have been used as the most authoritative source for the demographic assumptions for long-term demand analysis.

The extent to which demographic changes have been imperfectly forecast is indicated by the size and persistence of errors in global population projections since the 1950s, as demonstrated recently by the US National Academy of Sciences (Bongaarts and Bulatao, 2000). They show that errors in forecasts of country and regional populations have been as large as 17 per cent over 30 years. Duncan and Wilson (2004) argue that the latest global population projections by the UN Population Division may be seriously flawed because of the assumptions that were made about the future paths of fertility rates. In its 2000 revision (UN 2001), the UN assumed that in what they describe as "high fertility" developing countries (a group of 16 "least developed" countries, mostly in Africa) total fertility rates (the average number of children per woman in her lifetime) will not decline as fast as they had assumed previously. Also, for three populous developing countries (Bangladesh, India, and Nigeria), fertility rates are assumed not to decline as quickly as in earlier projections. Further, fertility rates in the "low fertility" countries (those developed and developing countries with total fertility rates below the replacement rate of 2.1) are not expected to continue to decline but are assumed at various points to move back up towards the replacement rate.

Given their population size, what happens to fertility rates in China and India will have a large impact on the size of the global population. In the case of China the UN has

[1] Bryant and McKibbin (1998), United Nations (2003).

assumed an increase in the total fertility rate (TFR) from the present 1.8 per cent to 1.9 per cent by 2010-15 and thereafter. The UN assumes that the TFR in Bangladesh and India will continue to decline until 2025 and then hold at the replacement rate of 2.1 per cent. Duncan and Wilson (2004) argue persuasively that there is no basis in the experience of other countries to support such assumptions.

There is no sign of a turnaround in fertility rates even in those countries that have already reached very low levels. It is obvious that there is limited understanding of the reasons for the fertility rate decline and especially for the persistence of rates below the replacement level. Thus, the assumptions by the UN of a turn-around in fertility rates in higher-income countries and a slowing of the decline in fertility rates in lower-income countries are highly doubtful. Maintenance of current fertility rates or a continuation of the existing downward trends would appear to be more appropriate assumptions.

2.2 Probabilistic population forecasting

Recognition of this inexactness has spawned a revolution in technical demography in the last decade that has emphasised stochastic population forecasting (Lee, 1999; Keilman, 2001; Wilson, 2002; Lutz, W., L, Sanderson, W. and Scherbov, S., 2001). Demographers have used three main approaches to handle the uncertainty of population forecasts—the uncertainty of the key variables including fertility and mortality:

1. extrapolate error levels of previous forecasts;
2. use time series modelling; and
3. adopt judgement methods mainly based on experts' opinions (Duncan and Wilson 2004).

The resulting demographic forecasts place surprisingly wide error bounds on forecast populations. Up until now, no consensus has emerged from these studies.

To address the economic implications of the population forecast errors highlighted by Bongaats and Bulatao (2000), we rely on the stochastic population projections reviewed and interpreted by Duncan and Wilson (2004).[2] While Bongaats and Bulatao focus on errors in particular historical forecasts, Duncan and Wilson offer a complete set of forecasts that combine the three approaches mentioned previously by demographers.

These stochastic forecasts deal with the uncertainty of the key variables such as fertility and mortality explicitly in Monte Carlo simulations. As a result, they generate not only forecasts (the median) of future population size and age structure, but also the confidence intervals (the error bands) of these forecasts. Yet trends in fertility and mortality are consistently downward and the rate of fertility decline has steepened.[3] Should this nonlinearity continue, even the new stochastic forecasts may mislead, at least as to measures of central tendency.

The results of these probabilistic forecasts of the world population and the associated confidence intervals are presented in Figure 1. The range of uncertainty of these set of new forecasts is quite large. There is a 60 per cent probability range of around one billion (7.6 to 8.6 billion). This indicates a 40 per cent chance that the global population in 2030 will be outside the 7.6 to 8.6 billions– an error range of almost 50% of the increment to the global population over that at the present. The 95 per cent probability range of the forecast is of 2.4 billion. Hence, there is a reasonable likelihood that the projection for 2030 could be 500 million too low or too high (ranging from 7.8 billion to 8.8 billion) and a small likelihood that the projection error could be more than one billion too high or too low.

In our simulations presented latter in the paper, the population inputs are based on these forecasts, but incorporate the effects of migration flows[4]. We use the forecasts—the median—as our baseline scenario of population size, and take error bands (confidence intervals) as our 'policy shocks' to analyse the economic implications of 'high' or 'low' population growth.

2.3 Population aging and its impact on food demand

The economic implications of recent demographic trends and uncertainties are the subject of an already substantial global literature. At minimum, this literature spans demography (McDonald and Kippen 2001, Booth *et al.* 2002), population economics (Mason 2003), public economics (OECD 1996, 1998), economic history (Bloom and

[2] Duncan and Wilson draw their stochastic projections from the recent work of Lutz *et al.* (1999, 2001).
[3] The steepening is clear from Duncan and Wilson, Figures 1-3.
[4] The details of the construction of our population forecasts are in the Appendix of this paper.

Williamson 1997; Williamson 1998), growth economics (Becker and Barro 1988; Barro and Becker 1989; Becker *et al.* 1990) and macroeconomics (Bryant and McKibbin 1998, 2001; Faruqee and Muhleisen 2002; Bryant *et al.* 2003). The latter macroeconomic research is most akin to this paper by virtue of its focus on international effects.[5] Its focus has, however, been on the industrialised regions of the northern hemisphere. Moreover, our study intends to explicitly track the age structure of the population and model its impact on the economy[6]. In this paper, however, the focus is on the implications of population sizes and distribution on food demand in Australia.

As fertility and death rates continue to decline a key consequence of this will be the aging of the global population, a process already well under way in the mature industrial economies. Even though most of the previous global population projections have over-estimated the fertility rate, they predict significant aging in many regions in the world during this century. While population aging has impacts on many aspects of an economy, it affects food demand both directly and indirectly.

The most rapidly aging economy is that of Japan, a country that is very important for Australian commodity exports. Japan's total fertility rate has been below 2.1 per cent since the early 1970s and had fallen to 1.3 per cent in 2000. In 2002, 24 per cent of Japan's population was 60 years and older and, according to the UN base line, by 2050, 42 per cent of its population will be in this age group (United Nations 2002). Japan's population is projected to begin to decline in 2007, but the decline may well begin before then. Total fertility rates have also reached very low levels in Western Europe, especially in the southern European countries. Those in Italy and Spain, for example, have been less than 1.2 per cent since the mid-1990s, and their populations are aging as quickly as Japan's. In Italy, the proportion of people aged 60 years and above is expected to increase from 24 per cent in 2002 to 41 per cent by 2050, while in Spain the UN expects the proportion to increase from 22 per cent in 2002 to 41 per cent by 2050. Declines in

[5] Much of this research was organised under a project coordinated by the Brookings Institution in the United States and involving staff from the International Monetary Fund. Finance is from the Economic and Social Research Institute of the Japanese Cabinet Office. A participant in the project was Professor Warwick McKibbin, of the ANU, who also holds an appointment at the Brookings Institution.

[6] Chan and Tyers (2004) build a model to track the changing global age and sex structure in the next few decades. Their results will be incorporated into our further studies of modelling the impact of demographic changes on the world economy and on Australian food export, in particular.

fertility have been even more dramatic in Central Europe and the former Soviet Union. There, total populations are already declining (Chan and Tyers 2004).

Yet this aging pattern is not restricted to the mature industrial economies. China's population is also aging very quickly. In 2002 the proportion of people aged 60 years and older in China accounted for 10 per cent of the total population. However, the UN base line has this proportion tripling to 30 per cent by 2050. Given the UN's conservative assumption about fertility decline in China, these projections of the aging of the population may well be under-estimated. Globally, the proportion of people aged 60+ years is expected to increase from 10 per cent in 2002 to 21 per cent in 2050. Again, if the UN's fertility rate assumption is flawed, as argued by Duncan and Wilson (2004), the proportion of aged may well grow faster than anticipated.

The United Nations expects that the proportion of the Australian population that is 60 years and older will increase from 16.4 per cent in 2002 to 29.9 per cent in 2050 (United Nations 2003). While Australia is not one of the more rapidly aging countries, the rate of aging is still quite high. The UN projects Australia's total fertility rate to remain well below natural replacement rate (2.1), falling to 1.67 in the period 2010-15 and then recovering a little to 1.85 by 2045-50. Clearly, migration will continue to contribute substantially to Australia's population growth and, since migrants tend to be young, it will tend to stem the acceleration of aging that is expected elsewhere in the industrialised world.

The transformation of diets with economic development and increasing per capita incomes has been well documented (Blandford 1984, Garnaut and Ma 1992, Mitchell *et al* 1997, and Wu and Wu 1997). As incomes grow from very low levels there is first an increase in consumption of the basic staples, which is effectively the overcoming of the under-nutrition associated with poverty. As incomes increase further, consumption of staples such as rice, corn and starchy root crops are replaced by wheat-based products such as bread and noodles. In this stage the consumption of protein-rich foods such as meats, vegetables and fruit begins to increase from very low levels. As per capita incomes approach developed country levels, consumption of meats, vegetables, fruits, and milk products form a larger and larger part of the diet. But within the high-income countries, and in some developing countries, there has been concern for some time over the high

level of consumption of animal fats and other products such as sugar and the adverse impact that consumption of these foods is having on health, with increasing incidence of heart disease and diabetes.

The fast-growing developing countries that have been through or are going through these phases in food consumption are now seeing their populations aging rapidly. What impact will this population aging have on consumption patterns in developing countries, alongside the income growth-related changes in diets that are still under way? What will be the impact of aging in the high-income countries? Good answers to these questions are not possible at present because the detailed information that is necessary for analysis of the impact of population aging on consumption patterns is generally not available.

Because women generally outlive men and eat less, and older people no longer in the workforce are less active and probably need fewer calories to maintain physical activity, we can expect that a larger proportion of older people will cause the quantity of food consumed per capita to decline. But there may be also changes in dietary patterns as people age because of changes in preferences and because of the manner in which food is served. For example, there is some evidence from the United States that older people eat more fresh fruit and vegetables, fish, and eggs, and prefer to eat at home more often than younger people (Lin *et al*., 2003). These age-related effects on food consumption have to be disentangled from the effects of changes in prices and income, and from the effects of migration from rural areas to urban areas and other changes in economic structure that lead to workers having more sedentary occupations.

One way to explore the direct linkage between population aging and food demand is to construct age-diet profile of consumers. A preliminary study of household survey data collected in China suggests that diets tend to change when people age (Duncan and Meng *et al*., 2004).[7] For example, the data for 1991 shows that for both the grains and the fruits and vegetables groups that a high level of consumption is maintained throughout the working-age years (up to the late fifties) and steadily declines thereafter. Dairy products show a tripling in consumption from the fifties onwards, which may be good news for dairy exporters. Analysis is being undertaken to sort out the effects of different factors

[7] The China Health and Nutrition Survey conducted by the Carolina Population Centre, University of North Carolina, Chapel Hill, USA.

such as income, price, activity level, age, and the 'cohort' effect on food intake in these households and the results should soon be available (Duncan and Meng *et al.,* 2004).[8]

3. THE ECONOMIC MODEL

The question of our interest requires a multi-sector, general equilibrium model of the world economy. The "*GTAP-Dynamic*" model has emerged to be one of the best models available. It is a recursively dynamic, applied general equilibrium model of the world economy that extends the standard comparative static GTAP model of Hertel (1997). The standard analytical structure of *GTAP-Dynamic* is described by Ianchovichina and McDougall (2000).[9]

The dynamic version of GTAP model offers a more complete characterisation of international capital mobility, capital accumulation and investment than the comparative static original. These additions are necessary in order to take advantage of the model's dynamics in capturing long run trends. It allows us to analyse the implications of changes in aggregate populations, labour forces and incomes for the composition of global food demand.

The structure of *GTAP-Dynamic* enables us to capture the demand side effects of population growth; namely its implications for per-capita incomes and hence both the volume of food consumption demand and Engel effects on it composition (Coyle *et al.* 1998 and Gehlhar and Coyle 2001). At the same time, the model captures the supply side implications of population growth, through changes in labour force size, capital-labour ratios and the pattern of comparative advantage between regions. Moreover, it achieves this at a high level of country and commodity disaggregation—up to 65 countries and regions of the world and 54 distinct commodities and product groups. This enables the

[8] The plan for further research is to separate out the price, income and age effects and use the estimated parameters in the global modelling to examine the impact of aging on world food consumption, particularly in the Asian area which will remain the main market for Australian exports. Analysis of the Chinese survey data is being split between the rural and urban households as there are large differences in average incomes between these groups of households. Estimated parameters from the two sets of analysis can therefore be used as proxies for age-related consumption effects in other low-income and middle-income developing countries.

[9] Applications of earlier versions are discussed in Ianchovichina *et al*. (1998).

assessment of changes in the international distribution of population and income on the demand for products in the full range from inferior through income-elastic.[10]

Given our focus on detailed food demand, we have opted for as extensive a listing of raw and processed food products as it is possible to extract from the GTAP database.[11] This list is provided in Table 1. The corresponding regional disaggregation is chosen to single out the large developing countries with comparatively uncertain population forecasts, including China, India and Indonesia.[12]

The GTAP framework has been used previously to examine long-term changes in global food demand and its composition, among others by Coyle *et al*. (1998), Cranfield *et al*. (1998) and Gehlhar and Coyle (2001). Only the comparative static version was employed in these exercises, however. The dynamic version offers a superior representation of the production process and the technical change and capital accumulation that drive it. It also embodies a well-researched set of behavioural parameters[13] for the supply side of the model and these we adopt with little modification.[14] Essential to the present task is that demand for commodities and other products be non-homothetic. This is achieved in GTAP with the use of the "constant difference of elasticities of substitution" (CDE) demand system. While there are limits to departures from unity of income elasticities of demand with this system it offers parametric economy combined with a generally representative range of income elasticities, as shown in Table 2.

[10] *GTAP-Dynamic* includes only a single representative household in each identified region, the population and (skilled and unskilled) labour force of which is projected exogenously at constant growth rates. In the current version, changes in age distributions cannot, therefore, be represented, nor can their influence on food demand be analysed. The introduction of a demographic sub-model to *GTAP-Dynamic* is part of an on-going project the preliminary stages of which are described by Chan and Tyers (2004). In this paper we focus on the role of aggregate population and labour force forecast errors. In particular, we use the standard model to investigate the sensitivity of projected consumption patterns to changes in regional and global population forecasts.

[11] The model, as currently constructed, runs on the GTAP Version 5 global database for 1997.

[12] The country groups chosen are indicated by the column headings in Table 2. Their precise composition is available on request from the authors.

[13] The GTAP database also has a relatively new set of behavioural parameters for consumption, based on detailed econometric analysis for "representative" countries. See Cranfield *et al*. (1998).

[14] We do alter the production side of the model to avoid the Leontief structure linking primary factor and intermediate input use. This is demonstrably unrealistic and the lack of any input substitutability causes extreme behaviour in the commodity markets that provide industrial inputs. We use an elasticity of substitution among intermediate inputs for all sectors of 0.5. The results are quite sensitive to this change of

4. APPLYING THE GTAP-DYNAMIC MODEL

The approach adopted is, first, to construct a reference, or baseline, scenario for the world economy over the period 1998-2030. A number of further simulations are then constructed that differ from the reference (baseline) one only in that the exogenous growth rates of populations and labour forces differ, in order to examine the impact of errors in projections of these variables.

4.1 Constructing a baseline projection

The construction of the reference scenario is a substantial task in itself. Not only does it require assumptions about the exogenous growth rates of primary factor supplies like labour and skill, it also rests importantly on assumptions about the pace of technical change and the extent of international capital mobility. The latter point is of particular importance because investment and capital accumulation drive the dynamics of this model. In our simulations we have chosen a level of international capital mobility that is at the high end of those available in the model, reflecting the increasing tendency for savings in some regions to finance investment in others.

Achieving realistic behaviour in the international distribution of investment requires careful consideration of risk premia. Otherwise, all new investment is concentrated in the developing countries where labour is abundant relative to capital and so the raw marginal returns on capital are highest. We have calibrated risk premia to observed investment behaviour between the base year, 1998, and the latest for which observations are available, 2003. The structure of the model enables the expected rate of return of investment cross the regions to converge over time.

Another issue for the simulation exercises is which population forecasts to use. The most systematic source of errors in past population forecasts has been the unexpected rapidity of the transitional decline in fertility in many large developing countries. Other contributors have been unexpectedly rapid declines in fertility in some industrialised

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parameters. A list of important elasticities used for the simulations are listed in Tables A2. and A3 in the Appendix.

regions, particularly in the former centrally planned economies, and the unexpected persistence of high death rates from infectious diseases, particularly in some African developing countries. Bongaarts and Bulatao (2000) find that mean absolute errors in past forecasts have grown to about five per cent over 30 years for industrialised countries and to between 15 and 25 per cent for developing countries over the same period.[15] To some extent, these errors have taken different directions and therefore had offsetting effects on global population forecasts. Whether this will be true in future population forecasts, or indeed, whether the sources of error in those forecasts bear any similarity to past errors remains to be seen. Resort is therefore necessary to the new stochastic population forecasts of the type constructed by Lee (1999) and Keilman (2001), and represented by Duncan and Wilson (2004). These are constructed by using Monte Carlo simulations that account for inter-temporal uncertainties in birth and age specific mortality rates. The baseline population growth rate is constructed based on the stochastic forecasts provided in Duncan and Wilson (2004). They offer no projection for Australia, however, so for this we resort to a local source (Booth *et al*. 2002) (see Appendix).[16]

A weakness in these forecasts is that they address the natural increase component of population growth only and lack explicit consideration of migration flows. While this makes little proportional difference in most of the world's regions, it is important for Australia, where up to half of the annual growth is due to net immigration. For this reason we add a non-stochastic 0.5 per cent per year to Australia's growth rate to account for net immigration.[17]

The supply of workers in each region is assumed to grow at the same pace as population, implying constant participation rates. The associated growth rates of skilled and unskilled labour are calculated to achieve an exogenous increase in the ratio of skilled to total labour by 2030 for each country/region. These ratios are consistent with those adopted by Walmsley and McDougall (2003). Their calculations are described in the Appendix.

[15] See Bongaarts and Bulatao (2000), Figure 2-3.
[16] A consequence of this is that the original stochastic analysis differs slightly for Australia from the simulations described by Duncan and Wilson. Australia's 2020 one standard deviation error bandwidth turns out to be slightly larger than for the OECD as a whole.
[17] We also add immigration to North America and West Europe.

The pace of technical change is incorporated by constructing a set of region-wide total factor productivity growth rates that are consistent with both the forecast changes in populations and labour supplies and with a set of non-controversial reference growth rates of GDP by region. These latter growth rates are similar to those used by Walmsley and McDougall (2003). We do this by making GDP growth rates exogenous in the first simulation and a corresponding set of region-wide total factor productivity growth rates endogenous. In this process, a number of modifications to the "standard" GDP projections were required to avoid seemingly unattainable productivity growth in some important developing countries. The GDP growth rates that were settled on are summarised in the central column of Table 3. Also listed are the corresponding growth rates of each region's population and the implied growth rates of regional per capita GDP. The implied labour force growth rates are shown in Table 4.

4.2 High and low population growth scenarios

In the high and low population growth simulations—the 'policy' scenarios, GDP is made endogenous in each region but the total factor productivity growth emerging from the reference simulation is held constant. Total income growth in each region therefore adjusts to the shock of slower or faster population growth. The projected GDP and GDP per capita when population growth is set to the limits of the 95% possibility band are also indicated in Table 3[18]. All the simulations show a positive relationship between regional GDP and regional population growth. More population means more labour to combine with the capital stock of any year and hence more output overall. Yet, consistent with its multi-region, Solow-Swan structure, the model yields a negative relationship between population and per capita income growth.

The multi-region structure of the model also captures interactions between population growth in one region and income growth in others. Because saving rates and labour force participation rates are held constant in our simulations, these interactions are of two types:

1) slower population growth in the rest of the world leads to higher per capita incomes there and hence a shift in consumption toward the more income elastic products; and

[18] Note that the figures listed are for indications only, since GDP growth rates are endogenous and therefore vary from scenario to scenario.

2) it reduces labour supply growth in the rest of the world relative to Australia, raising the return to investment and accelerating Australia's capital accumulation, especially in manufacturing, which is comparatively labour intensive. This shifts the international terms of trade in favour of manufactures.
Our primary interest is the implications of these terms of trade changes for Australia.[19]

Eight population growth scenarios that are deviate from the median of population forecasts—the baseline scenario—are simulated in order to compare with the latter. They are divided into four groups for convenience: 1) high and low population growth in the mature industrial (mainly OECD) countries, excluding Australia[20]; 2) high and low population growth in the developing countries; 3) high and low population growth in both the mature industrial (mainly OECD) and the developing countries, again excluding Australia — the 'world' case;[21] and 4) high and low population growth in Australia. These scenarios embody population projections that are in the range 2.5-97.5 per cent of the distribution of the forecast median. In other words, each group represents a 95% confidence interval of the population forecast in the corresponding regions. In these policy scenarios, population growth rates in other regions remain the same as in the baseline scenario (the median of the forecasts).

5. THE RESULTS

The baseline scenario is constructed to achieve reasonable GDP growth rates for the world from 1998 to 2030. The reference scenario on which we settled yields Australian export price trends shown in Figure 2. The real aggregate export price index for Australia increases by about 10% from its level in 1997. The most significant rise of export prices occur in the mineral and energy sectors, represented by the minerals industry in the diagram. Export prices of most agricultural products increase by less than 15% by 2030, while prices of manufactures change little (within 5% plus or minus). Figure 2 lists only a few products.

[19] For this reason, Table 3 does not show any interactive effects. Although the high and low population growth scenarios yield endogenous GDP growth rates, the scenarios are too numerous to detail all the interactions. The endogenous growth rates in the table stem from either high or low population growth in all developing countries or in all OECD countries.
[20] This case does not include Australia but includes the former Soviet Union and Central Europe regions.
[21] Because the group "rest of the world" did not match either category, its populations remained unshocked, along with Australia's, in the "world" cases.

Among the enormous amount of information provided by the results of the four groups of simulations, the focus is the impact of population forecast uncertainty on Australian economy, especially food demand. Note that population errors tend only to have significant effects beyond 2010. This is because the population errors are themselves small in the early years and because the growth process is driven by capital accumulation, the effects of which appear with a lag.

The impact of the 'world' and the Australian population scenarios on relevant variables are listed in Tables 5-8. The figures show percentage deviations from the results of the baseline scenario by 2030. Tables 5-7 focus on the effects of a *slower* global population growth. In this scenario, population growth is slower in all regions, except Australia whose population maintains baseline growth.

Table 5 shows that while all regions, including Australia, have higher GDP per capita, only Australia's GDP rises when it falls in all other regions[22]. Factors that contribute to higher GDP per capita in the rest of the world is different from that contribute to the similar outcome in Australia. For the former, it is the combination of slower population growth and the Solow-Swan structure of the model; for the latter, it is the expansion of output with the same size of labor force. Lower GDP in the rest of the world is the result of slower population growth, which reduces labour supply and therefore output. Higher GDP in Australia is due to more capital inflows from overseas.

The last row in Table 5 shows that Australia is the only region that has higher investment in this scenario. This can be explained by the changes of factor ratios in Australia versus that in the rest of the world. Slower population growth in these regions increases capital per worker relative to that in Australia. As a result, investment is drawn to Australia, where the rate of return on capital is now relatively high as its capital/worker ratio is relatively low. Note that due to the rise of capital/labour ratio in the world, rate of return on capital falls world-wide, which brings down investment in the world (-8.7% by 2030). As the table shows, the decrease of investment in the rest of the world is far more

[22] Note that figures of GDP per capita in Table 5 reflect the differences between the slower global population growth and the baseline scenario by 2030. These are not comparable to figures in Table 3.

than the increase of investment in Australia. Increased capital accumulations in Australia combine with the same labour force generate more output.

As expected, in this scenario, the Engel effect of increased income per capita in the world brings higher per capita consumption levels. More importantly, the composition of this growing consumption also changes. Higher per capita income in the world shifts this increased consumption towards more income-elastic goods, especially energy and manufactured commodities, relative to less income-elastic goods, such as food (see Table 6). These changed consumption pattern in the rest of the world has impact on Australia's food exports. The impact on Australia's consumption pattern, however, is relatively small and mixed. While Engel effect dominates the changes of consumption patterns in other regions, it is relatively small and in some cases substitution effects dominate, such as most of the agricultural goods.

The supply side effect is through factor prices, mainly the price of labour versus that of capital. Slower world population growth reduces labour force than otherwise, hence increases the price of labour relative to that of capital. Indeed, we observe rise of labour prices, fall of capital prices and declines of the rate of return on capital in these regions. Since capital is mobile in our model, the fall of the rate of return on capital occurs in all regions, including Australia, although its population growth is held constant. Since more investment is drawn from the rest of the world to Australia, price of capital falls even more. In the meantime, while wages rise in the rest of the world, we observe a slight decrease of wages in Australia. What we see here is a world-wide decline of the relative price of capital to labour. However, in Australia, where labour is relatively abundant in this scenario, labour is cheaper compared to the rest of the world.

Relatively cheaper labour in Australia encourages higher output in industries that are labour-intensive, especially manufactures. In Table 7, this reflects in the impact of Australian output by 2030: manufactures and services industries expand while most of agricultural sectors loss in output. In the rest of the world where capital is now relatively cheap, production shifts towards capital-intensive industries (see Table 7). For example, while outputs drop in all sectors in the regions with slower population growth, the 'oil and

gas' industry has the relatively small reduction of output, since it is highly capital-intensive in all the regions in the world[23].

These effects on supply and demand in Australia and overseas ultimately change the terms of trads and export demand from Australia. When other regions in the world grow slower as a result of lower labour supply, Australia's economy benefits from capital inflows from overseas and its output increases. Higher domestic production requires more imports to Australia, while demand from overseas for Australian export falls. As a result, Australia's terms of trade deteriorate.

The impacts of slower population growth in the world on the values of Australian exports by product, and on the volume of Australian output and exports are shown in Table 8 and Table 9, respectively[24]. These two tables also list the impact of three other population scenarios: faster population growth in the rest of the world, lower and higher population growth in Australia.

Slower global population growth affects Australia's exports adversely via the relative decline in demand abroad for its energy-minerals exports and for its less income elastic commodities. Interestingly, in this scenario sectors supplying relatively income-elastic products, including manufactures and services, are substantial gainers. By contrast, when the population of the rest of the world grows more quickly, Australia's commodity (both agricultural and natural resources) exports generally rise while manufacturing and service exports decline. This pattern arises via the two forces discussed above:
1) faster population growth reduces per capita income in the rest of the world, which tends to shift consumption towards non-energy primary commodities, which are less income elastic than energy, manufactures or services;
2) faster labour force growth cheapens labour relative to other factors, yielding more labour-intensive production techniques and reducing the relative cost in the labour-intensive industry groups, particularly manufactures. It also makes labour relatively more

[23] Details of the cost structure of each industry in all regions are available from the authors upon requests. It takes too much space to display all relevant information here.

[24] Impacts of various population scenarios on export prices are not shown here, mainly because there are no significant changes of prices. This can be seen by comparing the impact on export values with that on export volumes.

expensive in Australia compared to that in other regions, which shifts production in Australia away from its labour-intensive industries towards other sectors, including food.

Table 8 and in Table 9 also compare simulations with slower and faster population growth in Australia, but baseline rates in the rest of the world. Here the broad pattern is driven by Australia's labour supply. Faster population growth yields faster labour supply growth and increases output in the short term. In the long term it also raises investment and expands Australia's capital stock, thereby raising output in most sectors and the values of trade flows in both directions.

The impacts of the global and Australian population scenarios on food production and exports are quite significant, especially when we consider the total ranges generated by the 95% confidence intervals of the population forecast. To see this more explicitly, Figures 3 and 4 draw the impact on Australia's export volume of vegetable and fruits and on other grains. Figure 3 shows that faster/slower world population growth increases/decreases Australian export of vegetable and fruits by about 50 percentage points, or, about 10% deviation from the baseline scenario.

Does it matter where the population forecast error occur? In Tables 10 and 11, the results of faster and slower population growth in developing countries and in OECD countries[25] are compared. Here, the impact of population scenarios is similar to those discussed for the world population cases. Interestingly, though, the impact on individual sectors in Australia can be quite different, depending on where the population growth scenario occurs. For example, the volume of paddy rice export from Australia drops by over 10% (from the baseline scenario) when the population growth is slower in OECD, while it increases slightly (by 0.3% from the baseline scenario) when population growth rate is lower in developing countries (Table 11). Among agricultural products, the worst hit export sectors when population growth rate in developing countries is lower are: forestry (-18%), vegetable, fruit and nuts (-13%), fishing (-12%), and bovine cattle, sheep, goats and horses (-10%). The worse hit export sectors when population growth rate in OECD countries is lower include: paddy rice (-10%), oil seeds (-8%), and forestry (-7%).

[25] Note, this scenario includes Central Europe and Former Soviet Union countries, but excludes Australia.

Obviously, the differences in effects can not be simply attributed to the fact that developing countries' population (and therefore the size if the forecast error) is larger than that in OECD countries, because they are not only different in terms of scales, but also in terms of structure. These differences of impacts reflect differences in the structure of the economy in developing countries versus OECD countries: both in terms of demand and of supply (technology, etc), as well as the trade structure in the world.

Figures 5 and 6 also illustrate this point. In Figures 5, changes in population growth forecasts for developing countries and OECD countries have similar impact on Australian wheat export: when population growth rate is lower in these regions, demand for Australian wheat export falls. The difference is in terms of the scales: higher population growth in developing regions increases Australia's export volume of wheat by far more than a similar shock in OECD countries. However, the impacts of the same population scenarios in these two regions on export volume of cattle, sheep, goats and horses are quite different: slower population growth in developing countries *reduces* the export volume of these commodities; while a similar shock in OECD countries actually *increases* Australia's exports.

6. CONCLUSIONS AND THE PLAN FOR FURTHER STUDIES

The recent analysis of global population forecasts over the past 50 years confirms that errors have been considerable and that population forecasts have generally been upward-biased. Recent population projections by the UN Population Division appear to be too high because of the seemingly unwarranted assumptions made about the decline in fertility rates. New stochastic population projection methods have also yielded wide error bounds. Our use of *GTAP-Dynamic* allows the estimation of the economic consequences of global and regional population forecast errors for the performance of the global economy and the composition of Australian export demand. The results indicate that the growth rate of population in the rest of the world is important in Australia's economic health. Faster population growth overseas benefits Australia's producers of energy, minerals and agricultural products while slower population growth benefits its manufacturing and services sectors at the expense of non-energy primary commodities.

Our results also show that where population forecast error occurs matters to Australian food export. When population growth rate is slower than the forecasted median in developing countries, the worst hit agricultural sectors includes forestry and bovine cattle, etc, while slower population growth in other OECD countries most adversely affects farmers who produce paddy rice.

Although the current study only focuses on the scale of the population forecast error and its distribution in the world, the results suggest that the upward pressure on food prices implied by the forecasts of global demand and supply by FPRI (1995, 1996), may be overstated.[26]

Populations of most of the high-income countries and some of the developing countries are aging rapidly because of the declining fertility rates and increasing life expectancy. This population aging could have important implications for food demand. The issue is of importance for Australian food exports as the populations of Japan, the most important food importer, and China, which is rapidly becoming one of Australia's most important food importers, are both aging quickly. There is little known about how aging affects dietary patterns. Some general statements can be made but data available from China holds out promise for getting some firm answers to this question, at least for China (Duncan and Meng, *et al*., 2004).

The next step of this study is to explicitly model the impact of population aging on savings, consumptions (including consumption patterns) in the world and in Australia in particular. This will be done by replacing the single regional household in the current GTAP structure with several age-gender groups and model their consumption-saving behaviour. A demographic model that provides forecasts of the sizes of these groups is discussed in Chan and Tyers (2004).

[26] The use of projected rapid population growth in alarmist fashion continues, however, as in Leisinger *et al.* (2002).

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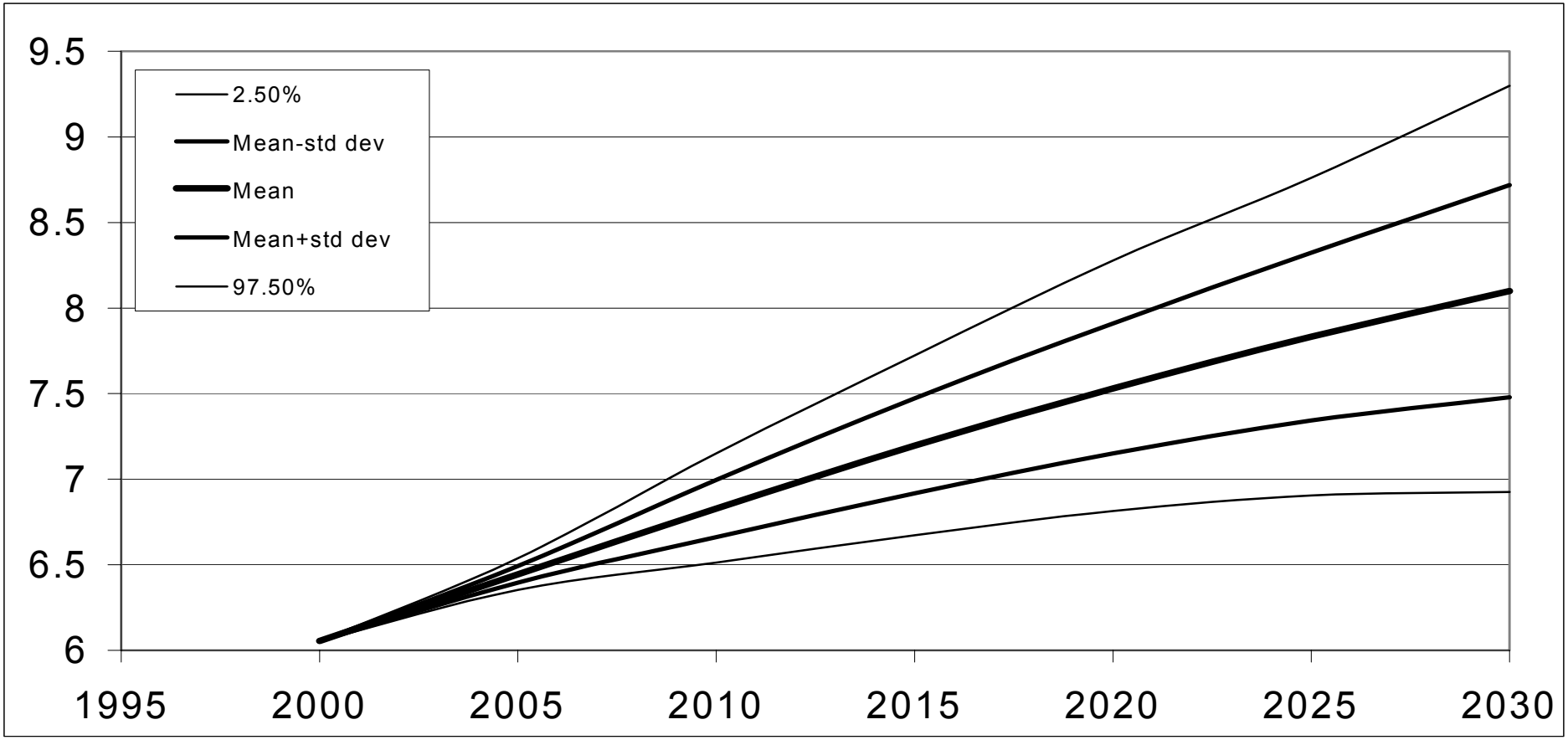
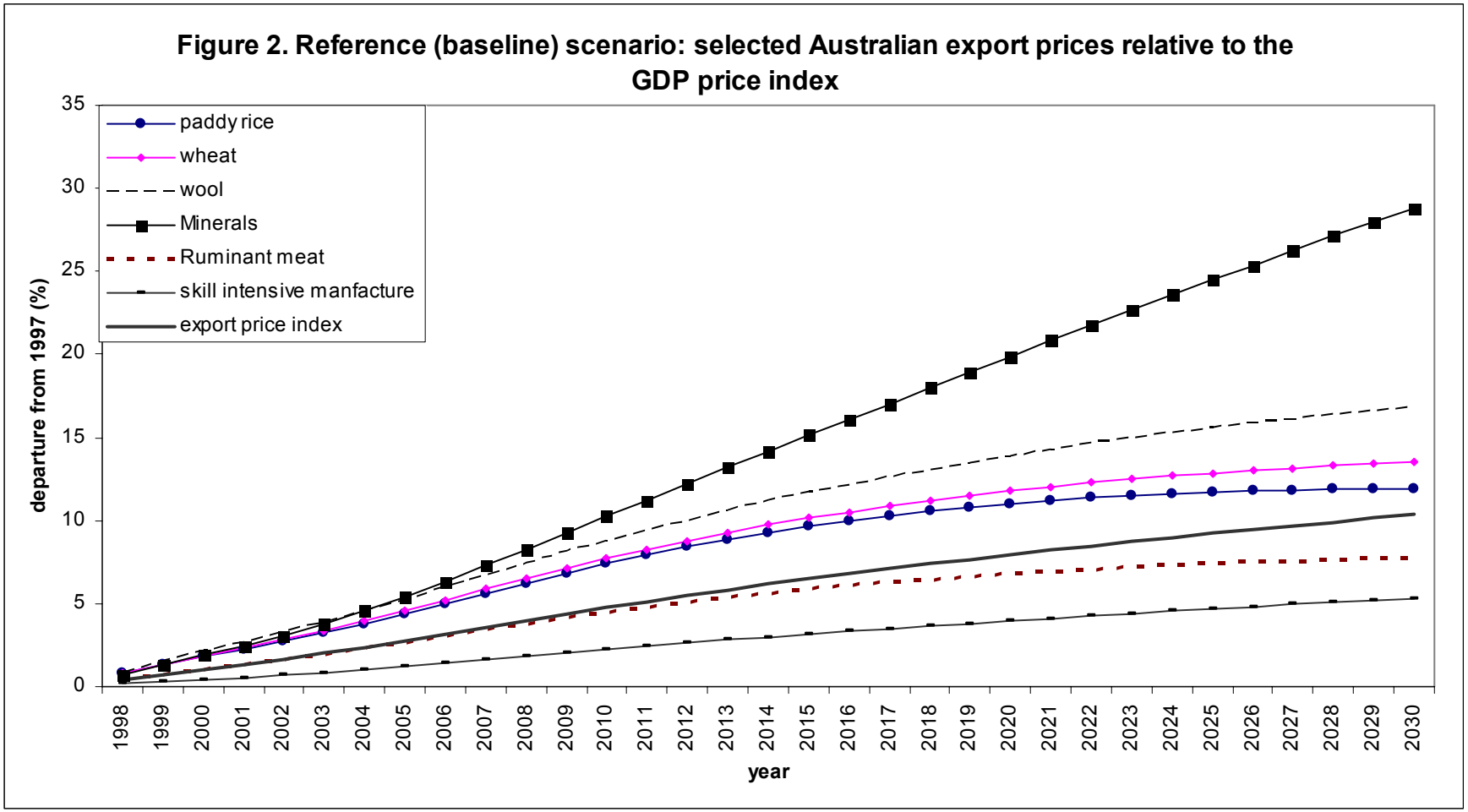
Figure 1: Confidence Intervals for Global Population Projections (billions)

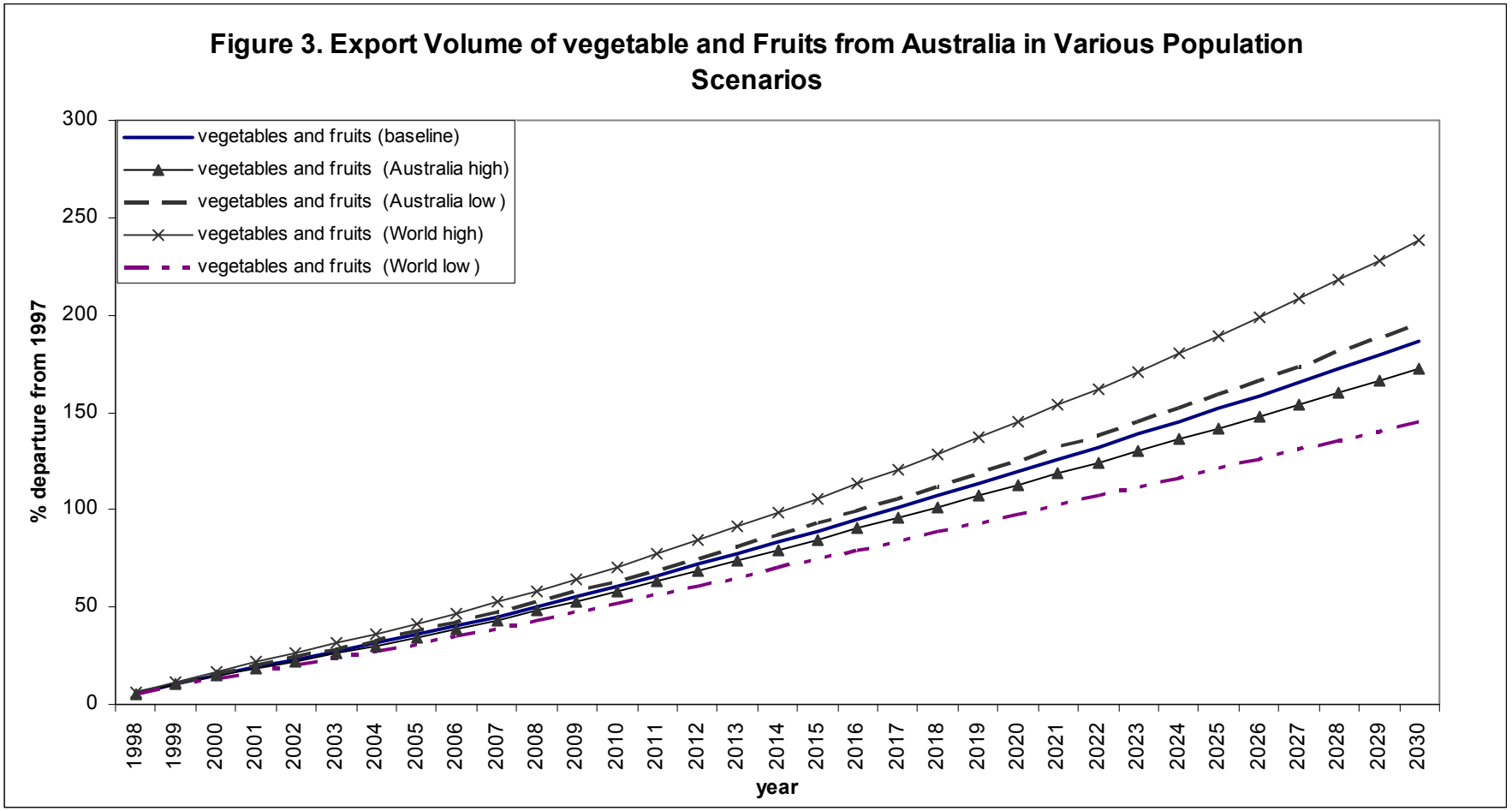


Source**:** Adapted from the stochastic population projections described by Duncan and Wilson (2004).

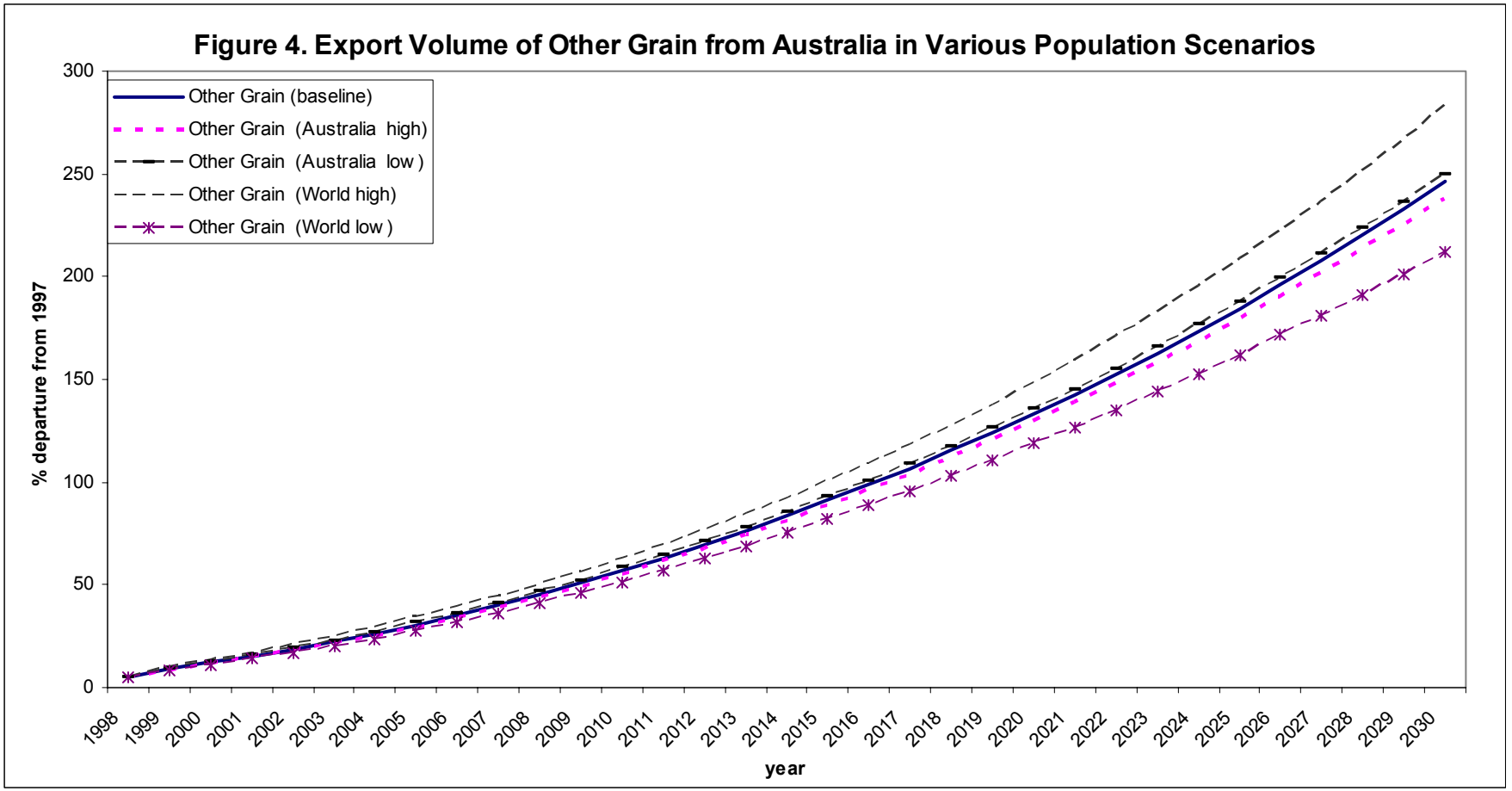
Figure 2. Reference (baseline) scenario: selected Australian export prices relative to the GDP price index



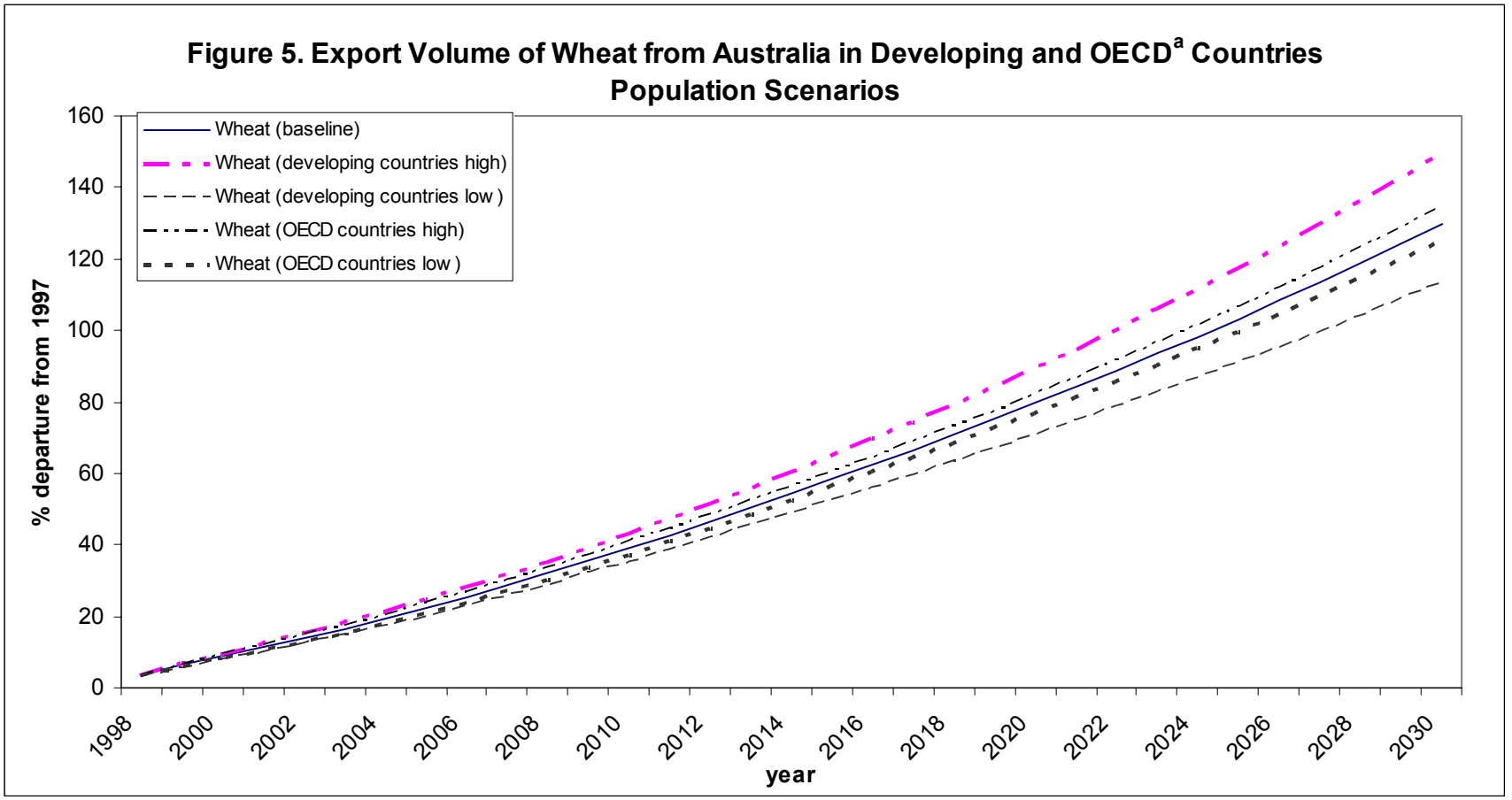
Source: based on the baseline simulation using version 5 database of GTAP-Dynamic, as described in the text.



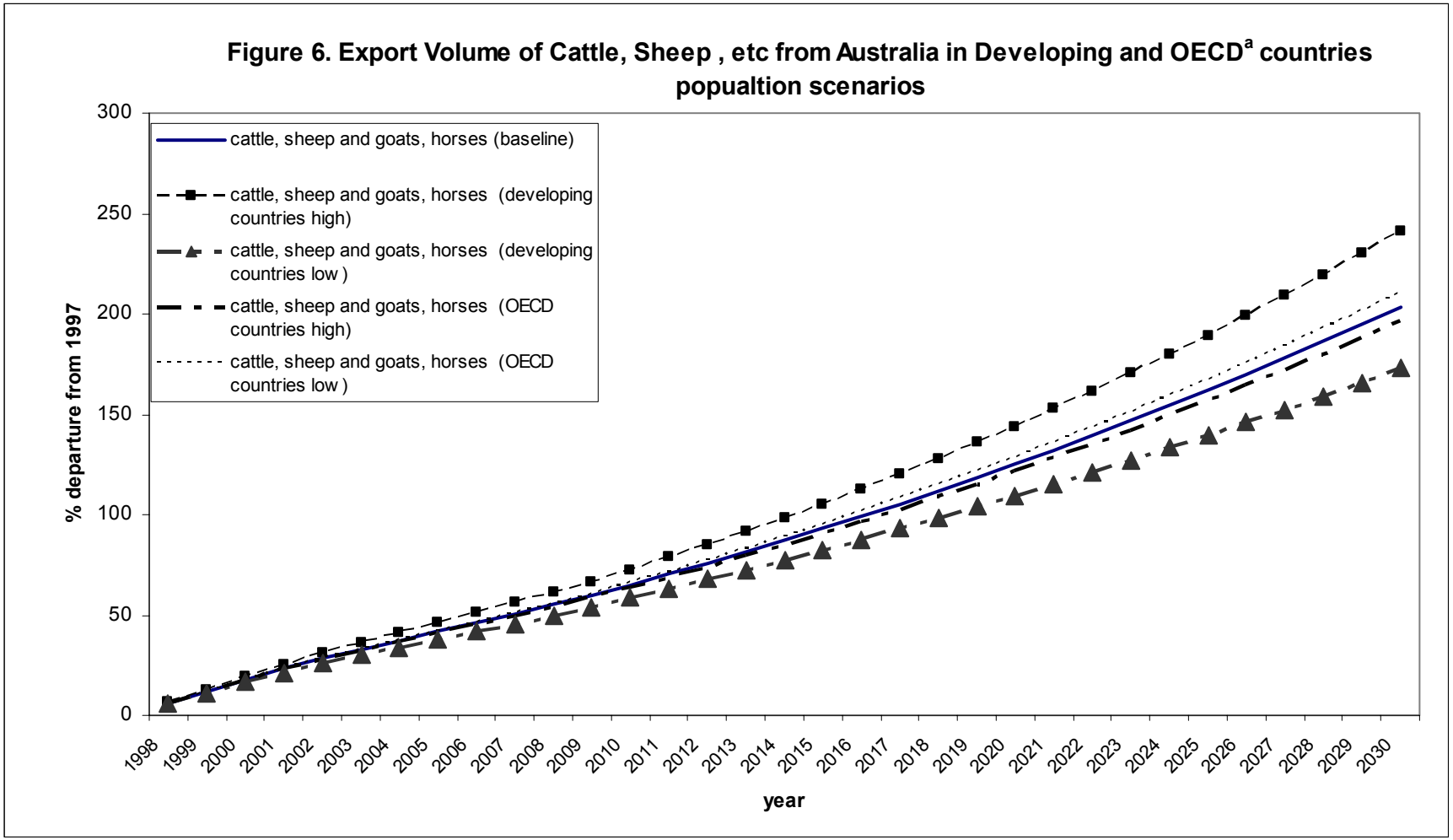
Source: simulation using version 5 data base of the Dynamic GTAP model.



Source: simulation using version 5 data base of the Dynamic GTAP model.



a. includes central Europe and former Soviet Union, but excludes Australia.
Source: simulation using version 5 data base of the Dynamic GTAP model.



a. includes Central Europe and Former Soviet Union, but excludes Australia.
Source: simulation using version 5 data base of the Dynamic GTAP model.

Table 1: Product groups included in the model

Agricultural product group	Processed food product group	Other products
Paddy rice	Processed ruminant and horse meat products	Coal
Wheat	Other meat and animal products	Oil and gas
Other cereal grains	Vegetables oils and fats	Minerals
Vegetables, fruit and nuts	Dairy products	Other labour intensive manufactures
Oil seeds	Processed rice	(excluding processed foods)
Sugar cane, sugar beet	Sugar	Skill intensive manufactures
Plant-based fibres	Other food products	Skill intensive services
Other crops	Beverages and tobacco products	Labour intensive services
Bovine cattle, sheep, goats and horses		
Pigs, poultry and other animal products		
Raw milk		
Wool, silk-worm cocoons		
Forestry		
Fishing		

Source: GTAP Version 5 Data Base. The full commodity list covers 54 products in all, of which the majority are manufactures and services.

Table 2: Income elasticities of demand implied by GTAP-Dynamic CDE parameters.

Product	North America	South America	Sup-Saharan Africa	Middle East, North Africa	Western Europe	Central Europe, former USSR	India	Other South Asia	Japan	China	Indonesia	Other East Asia	Australia	Rest of World
Paddy rice	0.21	0.2	0.55	0.35	0.18	0.18	0.29	0.34	0.1	0.45	0.4	0.22	0.16	0.34
Wheat	0.15	0.21	0.53	0.23	0.14	0.16	0.29	0.33	0.1	0.45	0.4	0.23	0.16	0.33
Other cereals	0.09	0.25	0.46	0.25	0.19	0.17	0.29	0.33	0.1	0.29	0.4	0.17	0.16	0.33
Veg ,frt, nuts	0.37	0.51	0.6	0.58	0.31	0.53	0.67	0.71	0.32	0.85	0.65	0.53	0.14	0.55
Oil seeds	0.13	0.46	0.6	0.59	0.29	0.53	0.67	0.75	0.32	0.81	0.65	0.53	0.14	0.55
Sgr cane/beet	0.48	0.52	0.61	0.53	0.38	0.52	0.67	0.75	0.32	0.91	0.65	0.69	0.14	0.55
Plant fibres	0.51	0.53	0.58	0.6	0.3	0.54	0.67	0.75	0.32	0.79	0.65	0.65	0.14	0.55
Other crops	0.36	0.6	0.58	0.61	0.29	0.52	0.67	0.74	0.32	0.5	0.65	0.51	0.14	0.57
Cattle, sheep	0.36	0.38	0.61	0.65	0.3	0.48	0.63	0.79	0.47	0.95	0.76	0.43	0.18	0.53
Pig, poultry	0.36	0.51	0.61	0.65	0.28	0.47	0.63	0.8	0.47	1.11	0.76	0.49	0.18	0.53
Raw milk	0.34	0.36	0.53	0.48	0.25	0.29	0.58	0.64	0.52	0.79	1.06	0.48	0.12	0.48
Wool, silk	0.72	0.9	0.7	0.87	0.76	0.85	0.8	0.93	0.8	0.96	0.82	0.78	0.85	0.83
Forestry	1.08	1.24	1.44	1.26	1.09	1.22	1.58	1.47	1.08	1.19	1.36	1.2	1.11	1.24
Fishing	0.46	0.57	0.58	0.59	0.43	0.52	0.67	0.73	0.32	0.79	0.65	0.59	0.14	0.55
Coal	0.84	1.09	0.9	1.03	0.97	0.97	0.99	1.12	0.94	1.3	1	0.95	1	0.94
Oil & gas	0.94	1.01	0.89	1.03	0.93	0.97	0.99	1.12	0.94	1.02	1	0.94	1	0.98
Minerals	1.08	1.2	1.4	1.18	1.08	1.26	1.58	1.47	1.08	1.15	1.36	1.27	1.11	1.22
Ruminant meat	0.35	0.42	0.62	0.6	0.32	0.32	0.63	0.91	0.47	0.39	0.76	0.41	0.18	0.48
Other meat	0.35	0.43	0.62	0.6	0.32	0.37	0.63	0.94	0.47	0.83	0.76	0.46	0.18	0.53
Veg oils	0.36	0.49	0.58	0.58	0.27	0.53	0.67	0.75	0.32	0.82	0.65	0.56	0.14	0.53
Dairy products	0.28	0.32	0.57	0.48	0.21	0.29	0.58	0.66	0.52	0.32	1.06	0.54	0.12	0.45
Processed rice	0.24	0.22	0.58	0.34	0.21	0.17	0.29	0.28	0.1	0.42	0.4	0.18	0.16	0.34
Sugar	0.41	0.54	0.58	0.6	0.31	0.53	0.67	0.74	0.32	0.69	0.65	0.63	0.14	0.5
Other food	0.35	0.5	0.58	0.58	0.31	0.53	0.67	0.71	0.32	0.69	0.65	0.54	0.14	0.55
Bev, tobacco	0.74	0.9	0.77	0.89	0.86	0.87	0.85	0.98	0.85	0.92	0.87	0.86	0.91	0.87
Lab-int mfg	0.91	1.02	0.94	1.05	0.97	0.99	0.89	0.99	0.93	0.94	1	0.94	1	0.98
Ski- int mfg	1.06	1.17	1.23	1.2	1.09	1.14	1.52	1.43	1.08	1.07	1.28	1.11	1.1	1.19
Ski-int srv	1.06	1.23	1.41	1.24	1.13	1.17	1.6	1.48	1.09	1.17	1.4	1.22	1.12	1.25
Lab-int srv	1.05	1.18	1.2	1.17	1.09	1.13	1.38	1.36	1.09	1.13	1.27	1.15	1.08	1.16

Source: GTAP Version 5 Data Base. These Engel elasticities are implied by the parameters of the GTAP Constant Difference of Elasticities of Substitution (CDE) functions use to represent demand. See Huff et al, 1997. They are calculated from the model by simulating pure income shocks over a single year.

Table 3: Simulated population, GDP and GDP per capita growth rates, 1995-2030[a]

Country/region	Population growth rate[b]			GDP growth rate			Growth rate of GDP per capita		
	Low	Base line	High	Low[c]	Base line[b]	High[c]	Slow[c]	Base line[d]	High[c]
North America	0.4	0.9	1.3	2.5	2.9	3.2	2.1	2.0	1.9
South America	0.8	1.3	1.8	2.9	3.3	3.6	2.1	2.0	1.9
Sub-Saharan Africa	1.3	2.0	2.6	3.1	3.6	4.1	1.8	1.6	1.5
Middle-East and North Africa	1.2	1.7	2.2	3.0	3.3	3.6	1.7	1.5	1.4
West Europe	-0.1	0.2	0.5	2.3	2.5	2.7	2.4	2.3	2.2
Central/East Europe and FSU	-0.7	-0.2	0.1	3.0	3.3	3.6	3.7	3.6	3.5
India	0.8	1.4	1.9	3.7	4.0	4.2	2.9	2.6	2.3
Other South Asia	0.8	1.4	1.9	3.6	3.9	4.2	2.8	2.5	2.3
Japan	-0.2	0.1	0.5	1.7	1.9	2.2	1.9	1.8	1.7
China	0.1	0.5	0.8	4.6	4.8	5.1	4.5	4.4	4.3
Indonesia	0.6	1.1	1.6	4.0	4.2	4.5	3.4	3.1	2.9
Other East and SE Asia	0.6	1.1	1.6	4.6	4.9	5.3	4.0	3.8	3.7
Australia	0.6	0.9	1.3	3.0	3.3	3.7	2.5	2.4	2.3

a Actual growth rates vary by year as population projections show slowing growth. This table includes averages through 2030 for illustration purposes only.
b Exogenous.
c Endogenous, given productivity growth implied in the base line scenario. Figures for developing countries are from population shocks of these countries, the same for OECD countries and Australia. Central/East Europe and FSU and Rest of the world are not included in any of the shocks.
d Implied by the exogenous rates of GDP and population growth in the base line scenario.
Sources: Exogenous growth rates are from Walmsley and McDougall (2003). Endogenous rates are from simulations of the GTAP-Dynamic model as explained in the text.

Table 4: Implied labour force growth rates, 1997-2030 [a]

Country/region	All labour			Production labour			Professional labour		
	Low	Base line	High	Low	Base line	High	Low	Base line	High
North America	0.41	0.88	1.29	-0.02	0.44	0.85	1.05	1.52	1.93
South America	0.82	1.25	1.76	-0.06	0.34	0.84	3.01	3.47	4.05
Sub-Saharan Africa	1.25	1.96	2.57	0.91	1.60	2.21	4.76	5.51	6.32
Middle-East and North Africa	1.24	1.72	2.19	0.45	0.90	1.37	3.75	4.25	4.82
West Europe	-0.12	0.22	0.53	-0.55	-0.21	0.10	0.51	0.86	1.18
Central/East Europe and FSU	-0.68	-0.25	0.13	-1.11	-0.68	-0.30	-0.06	0.38	0.77
India	0.80	1.38	1.91	0.35	0.91	1.44	2.82	3.42	4.02
Other South Asia	0.80	1.38	1.91	0.35	0.91	1.44	2.82	3.42	4.02
Japan	-0.24	0.13	0.51	-0.67	-0.30	0.07	0.39	0.77	1.15
China	0.09	0.46	0.80	-0.42	-0.07	0.27	1.83	2.21	2.59
Indonesia	0.62	1.10	1.57	-0.19	0.26	0.73	2.53	3.03	3.56
Other East and SE Asia	0.62	1.10	1.57	-0.44	0.00	0.48	2.84	3.34	3.89
Australia	0.57	0.94	1.32	0.13	0.50	0.88	1.20	1.57	1.97

a Actual growth rates vary by year as population projections show slowing growth. This table includes averages through 2030 for illustration purposes only. Note that these rates are based on the assumption that labour force participation rates remain constant in all regions.

Sources: Population growth rates summarised in the first three columns of Table 3. Increasing skill shares are modelled as explained in the text, based on the time trends adopted by Walmsley and McDougall (2003).

Table 5. The impact of slower global population growth on 2030 GDP and investment

(% departure from reference scenario)

	North America	South America	Sup-Saharan Africa	Middle East, North Africa	Western Europe	Central Europe, former USSR	India	Other South Asia	Japan	China	Indonesia	Other East Asia	Australia
GDP	-10.7	-6.9	-13.3	-6.8	-6.9	-8.9	-5.9	-8.4	-8.1	-6.7	-5.3	-6.2	3.3
GDP/per capita	4.1	7.4	9.0	8.9	4.3	5.1	13.7	10.7	4.0	5.4	10.9	9.9	3.3
Investment	-9.7	-2.9	-13.2	-1.9	-5.4	-7.4	-1.3	-4.5	-7.4	-3.5	-1.4	-1.3	10.7

Source: simulation results described in the text, where population growth in the world (except Australia and the rest of the world is slower).

Table 6: The impact of slower global population growth on per capita consumption by 2030 (% departure from the reference scenario)

Product	North America	South America	Sup-Saharan Africa	Middle East, North Africa	Western Europe	Central Europe, former USSR	India	Other South Asia	Japan	China	Indonesia	Other East Asia	Australia
Paddy rice	2.1	1.8	5.6	2.8	0.8	0.7	3.7	3.5	0.3	2.4	3.5	2.0	0.3
Wheat	1.3	1.9	5.4	1.8	0.5	0.6	3.6	3.4	0.3	2.4	3.4	1.9	0.2
Other cereals	0.7	2.2	4.9	1.9	0.7	0.6	3.8	3.5	0.4	1.6	4.0	1.5	0.2
Veg ,frt, nuts	3.4	4.5	6.3	4.5	1.2	2.1	9.0	8.1	1.7	4.6	7.1	5.7	0.2
Oil seeds	1.1	4.4	6.2	4.5	1.5	2.2	9.1	8.5	2.1	4.6	6.2	5.5	0.2
Sgr cane/beet	4.1	4.4	6.1	4.1	1.5	2.1	9.1	8.4	1.8	4.9	6.5	5.8	0.2
Plant fibres	3.5	4.0	5.9	4.4	1.4	2.1	9.0	8.2	1.9	4.1	6.3	5.2	0.2
Other crops	4.0	4.9	5.9	4.9	1.4	2.6	9.0	8.0	1.6	3.4	5.8	5.4	0.2
Cattle, sheep	2.3	3.3	6.3	4.9	1.1	1.9	8.5	8.2	2.5	5.2	6.9	4.7	0.2
Pig, poultry	2.9	4.3	6.6	4.9	1.1	1.9	8.5	8.7	2.1	5.9	7.6	4.5	0.2
Raw milk	2.1	3.2	5.7	3.7	0.9	1.1	7.8	7.1	2.8	4.1	10.4	4.8	0.1
Wool, silk	4.6	8.4	7.2	6.2	4.9	3.8	9.4	9.8	5.2	4.8	6.1	8.4	1.5
Forestry	10.7	10.8	15.6	10.9	7.6	6.1	18.5	14.5	6.1	5.5	11.8	12.2	-1.2
Fishing	4.1	5.6	7.9	6.4	2.6	2.6	10.2	7.8	2.4	4.7	7.2	6.2	0.2
Coal	12.6	9.9	12.1	9.3	8.5	6.1	11.7	11.3	9.4	7.4	9.5	9.9	4.3
Oil & gas	12.3	10.3	9.5	9.7	9.5	6.6	11.8	11.6	9.4	8.3	9.3	11.4	2.8
Minerals	10.6	9.4	14.2	9.5	7.4	5.9	17.7	14.3	6.5	6.0	11.2	10.9	0.8
Ruminant meat	2.6	3.3	6.3	4.2	1.2	1.2	7.4	9.6	2.1	2.3	6.6	3.8	0.2
Other meat	2.1	3.3	5.9	4.4	1.2	1.4	7.0	10.0	1.8	4.4	6.5	3.8	0.2
Veg oils	2.2	3.7	5.5	4.1	1.0	2.1	7.9	7.1	1.8	4.1	5.0	4.6	0.1
Dairy products	1.8	2.4	5.2	3.4	0.7	1.1	6.9	6.2	2.0	1.6	8.3	4.4	0.1
Processed rice	1.6	1.7	5.6	2.6	0.9	0.6	3.6	2.8	0.3	2.1	3.6	1.7	0.2
Sugar	2.8	3.9	5.3	4.1	1.2	2.2	8.1	7.2	1.3	3.5	5.6	5.2	0.1
Other food	2.0	3.6	5.4	4.0	1.1	2.0	8.0	6.8	1.2	3.5	5.1	4.5	0.1
Bev, tobacco	4.3	5.9	6.7	5.8	3.5	3.2	10.1	9.5	3.1	4.2	6.7	6.6	0.6
Lab-int mfg	4.2	6.2	7.6	6.5	3.1	3.5	9.2	8.6	2.6	3.8	7.3	6.8	-0.5
Ski- int mfg	5.2	7.3	10.2	8.1	3.7	4.5	15.8	12.6	3.4	4.4	9.4	8.5	-0.1
Ski-int srv	4.1	6.3	10.4	6.8	3.8	4.1	16.1	12.1	3.1	4.0	9.7	7.7	-0.1
Lab-int srv	4.5	7.0	9.1	7.2	4.0	4.0	13.8	11.2	3.5	4.2	9.1	8.3	0.6

Source: simulation of slower population growth in the world, except the regions of 'Australia' and the 'Rest of the World', using GTAP V5 database.

Table 7: The impact of slower global population growth on regional output by 2030 (% departure from the reference scenario)

Product	North America	South America	Sup-Saharan Africa	Middle East, North Africa	Western Europe	Central Europe, former USSR	India	Other South Asia	Japan	China	Indonesia	Other East Asia	Australia
Paddy rice	-8.7	-7.8	-14.7	-11.4	-15.8	-12.4	-11.6	-12.3	-10.0	-7.1	-9.0	-6.5	-4.6
Wheat	-8.0	-6.1	-12.2	-11.3	-10.7	-11.7	-12.1	-9.5	-12.1	-6.6	-18.0	-9.5	-7.8
Other cereals	-9.3	-6.3	-14.1	-10.4	-10.5	-11.8	-7.8	-7.9	-10.6	-5.7	-6.8	-5.7	-2.0
Veg ,frt, nuts	-9.4	-6.7	-13.0	-9.6	-11.3	-11.2	-5.1	-7.7	-9.4	-6.8	-6.8	-6.3	-3.8
Oil seeds	-8.0	-5.3	-12.0	-9.5	-11.2	-14.1	-6.1	-6.1	-13.2	-5.5	-4.0	-4.7	-5.0
Sgr cane/beet	-8.4	-7.0	-13.4	-9.0	-9.0	-11.6	-6.4	-7.1	-8.9	-5.9	-4.5	-6.0	-2.3
Plant fibres	-7.6	-6.7	-7.2	-8.8	-12.4	-16.7	-4.8	-1.9	-7.9	-6.1	-0.3	0.2	-4.4
Other crops	-5.2	-4.3	-10.4	-10.9	-12.2	-12.8	-4.2	-5.0	-9.2	-6.5	1.3	-3.0	-1.7
Cattle, sheep	-9.9	-7.4	-13.5	-8.9	-9.5	-11.3	-7.7	-8.9	-8.7	-4.3	-3.7	-6.2	-2.2
Pig, poultry	-10.5	-7.0	-12.5	-8.7	-9.9	-12.0	-7.5	-6.9	-9.4	-5.6	-4.6	-6.8	-0.7
Raw milk	-10.3	-7.5	-13.9	-9.1	-9.3	-11.0	-8.2	-8.0	-8.4	-4.5	-3.9	-8.1	0.0
Wool, silk	-12.5	-3.6	-12.2	-7.5	-11.8	-12.1	2.1	-1.6	-6.8	-4.1	-9.5	-2.3	-2.0
Forestry	-7.7	-4.1	-6.1	-3.3	-4.9	-9.4	-2.1	-5.2	-7.1	-6.4	-2.6	-2.7	1.8
Fishing	-6.9	-5.7	-11.3	-6.7	-7.2	-11.9	-7.4	-9.5	-7.5	-6.4	-4.8	-6.8	-2.6
Coal	-4.8	-3.5	-5.9	-3.2	-4.4	-7.2	-3.0	-3.9	-4.7	-4.2	-2.4	-3.4	-1.4
Oil & gas	-4.1	-2.4	-3.3	-2.4	-3.3	-3.6	-2.2	-2.7	-3.2	-2.3	-2.3	-1.8	-0.7
Minerals	-6.8	-4.2	-5.5	-3.4	-5.6	-7.9	-5.2	-4.6	-6.2	-4.7	-3.6	-2.9	-0.5
Ruminant meat	-10.7	-8.6	-13.9	-9.8	-9.6	-11.4	18.1	-6.0	-9.2	-6.1	-7.0	-7.4	-2.6
Other meat	-11.6	-8.5	-14.5	-9.3	-9.2	-11.6	0.2	-7.2	-9.9	-6.2	-6.7	-8.9	0.8
Veg oils	-9.7	-7.9	-14.2	-10.6	-9.5	-12.4	-6.2	-7.2	-7.9	-6.3	-9.8	-10.1	1.1
Dairy products	-11.2	-10.3	-15.2	-10.3	-9.5	-12.0	-10.3	-8.8	-9.5	-8.2	-0.6	-9.8	-0.2
Processed rice	-15.7	-11.1	-16.0	-13.9	-11.5	-12.7	9.8	-14.1	-10.5	-8.6	-10.7	-8.9	-4.3
Sugar	-10.5	-8.7	-14.7	-10.3	-9.6	-12.4	-9.5	-10.1	-9.5	-7.4	-7.4	-7.9	-3.0
Other food	-12.0	-8.8	-14.1	-10.2	-9.4	-11.6	-0.7	-6.9	-10.2	-6.6	-8.7	-8.0	-0.3
Bev, tobacco	-10.6	-7.7	-15.0	-8.7	-7.5	-10.8	-7.9	-8.0	-8.5	-7.1	-8.3	-8.6	1.6
Lab-int mfg	-11.8	-7.2	-16.5	-8.7	-7.1	-10.0	-7.0	-9.0	-8.0	-6.9	-4.8	-7.1	5.3
Ski- int mfg	-10.8	-6.0	-13.4	-3.3	-6.9	-7.2	-5.6	-8.0	-6.9	-6.1	-4.1	-4.2	7.9
Ski-int srv	-10.9	-8.5	-15.8	-9.5	-7.1	-9.5	-7.9	-10.8	-8.4	-8.0	-7.3	-8.2	1.8
Lab-int srv	-10.4	-5.9	-14.5	-6.2	-6.4	-9.0	-5.8	-8.8	-8.0	-6.2	-5.0	-5.1	4.3

Source: simulation of slower population growth in the world, except the regions of 'Australia' and the 'Rest of the World', using GTAP V5 database.

Table 8: Effects on Australian real 2030 export values of changes in global population scenario[a]

(Per cent departures from base line projections)

Product	World[b] Low	World[b] High	Australia Low	Australia High
Paddy rice	-10.9	13.9	-2.4	1.2
Wheat	-10.7	13.8	-3.3	2.7
Other cereal grains	-10.7	12.9	-2.3	1.5
Vegetables, fruit and nuts	-15.5	22.3	-0.7	-0.6
Oil seeds	-13.0	16.7	-2.6	1.8
Sugar cane, sugar beet	-12.1	14.8	-0.2	-1.3
Plant-based fibres	-7.6	8.6	-1.8	1.1
Other crops	-11.6	15.9	-1.6	0.3
Cattle, sheep, goats and horses	-8.6	12.4	-2.3	1.4
Pig, poultry and other raw prod	-5.2	6.3	-3.8	2.3
Raw milk	-5.9	6.7	-3.2	1.6
Wool, silk-worm cocoons	-6.3	6.9	-2.8	2.4
Forestry	-22.3	30.4	9.1	-11.8
Fishing	-18.9	24.9	3.6	-5.4
Coal	-9.1	10.2	-1.4	0.9
Oil & gas	-16.1	18.9	5.0	-5.8
Minerals	-9.0	10.5	0.3	-1.3
Proc ruminant and horse prod	-6.4	6.8	-6.2	5.7
Proc pig, poultry and other meat	-3.4	3.2	-5.4	4.6
Vegetable oils and fats	-5.3	6.4	-8.5	8.6
Dairy products	-2.6	2.1	-6.4	5.9
Processed rice	-10.4	13.8	-6.4	5.8
Sugar	-7.0	8.2	-5.7	5.1
Other processed food products	-4.1	3.9	-9.9	10.1
Beverages and tobacco products	4.3	-6.9	-12.7	13.4
Other labour-intensive manufactures	7.0	-9.4	-14.1	15.3
Skill intensive manufactures	9.5	-11.1	-12.4	13.2
Skill intensive services	4.1	-6.6	-12.5	13.6
Labour intensive services	3.0	-5.1	-9.7	10.2
All exports	1.8	-2.6	-8.7	9.0

a Real values are measured relative to the Australian GDP deflator

b Excluding Australia and 'rest of the world'.

Source: Projections using the dynamic model described in the text.

Table 9: Effects on Australian 2030 output and export volumes of changes in world population scenario[a]

(Per cent departures from base line projections)

Industry	% departure from reference or base line scenario							
	World low		**World high**		**Australia low**		**Australia high**	
	Output	**Exports**	**Output**	**Exports**	**Output**	**Exports**	**Output**	**Exports**
Paddy rice	-4.6	-10.0	5.6	11.2	-5.9	0.9	6.0	-2.3
Wheat	-7.8	-9.3	8.8	10.5	-1.5	-0.4	1.1	-0.3
Other cereal grains	-2.0	-9.9	2.0	10.7	-5.7	1.1	6.1	-2.3
Vegetables, fruit & nuts	-3.8	-14.4	5.0	18.3	-5.0	3.2	5.2	-4.9
Oil seeds	-5.0	-11.9	5.9	13.4	-4.0	0.6	3.9	-1.6
Sugar cane, sugar beet	-2.3	-11.0	2.3	11.8	-5.8	3.8	5.9	-5.6
Plant-based fibres	-4.4	-5.6	4.1	5.2	0.3	1.7	-0.8	-2.5
Other crops	-1.7	-10.9	2.2	13.5	-5.7	1.9	6.0	-3.5
Cattle, sheep	-2.2	-7.7	2.6	10.0	-5.5	1.1	5.6	-2.3
Pig, poultry	-0.7	-4.6	0.9	5.0	-6.7	-1.0	7.0	-0.8
Raw milk	0.0	-5.4	-0.3	5.4	-7.7	-0.2	8.3	-1.7
Wool, silk-worm cocoons	-2.0	-5.1	1.7	4.7	-2.3	0.5	2.3	-1.1
Forestry	1.8	-25.4	-1.4	32.9	-6.3	15.5	6.5	-18.2
Fishing	-2.6	-18.5	3.5	21.7	-4.8	8.6	5.3	-10.6
Coal	-1.4	-4.7	1.4	4.4	-0.8	2.5	0.8	-3.0
Oil and Gas	-0.7	-14.1	0.8	14.4	-1.0	10.2	1.0	-10.8
Minerals	-0.5	-9.4	0.8	9.9	-3.1	4.4	3.2	-5.6
Ruminant meats	-2.6	-6.4	2.5	6.1	-7.2	-4.6	7.6	4.0
Pig, poultry meats	0.8	-3.0	-0.7	2.4	-9.3	-3.2	10.6	2.2
Vegetable oils and fats	1.1	-5.6	-0.8	6.4	-10.7	-7.2	12.4	7.6
Dairy products	-0.2	-2.3	0.0	1.6	-8.3	-4.7	9.1	4.1
Processed rice	-4.3	-10.2	5.4	12.4	-7.7	-4.6	8.2	4.0
Sugar	-3.0	-6.7	3.2	7.1	-6.8	-3.7	7.1	3.0
Other processed foods	-0.3	-4.4	0.3	4.0	-10.5	-9.0	12.1	9.5
Beverages and tobacco products	1.6	4.4	-1.8	-6.6	-8.9	-11.7	10.2	12.8
Labour-intensive mfg	5.3	6.2	-5.2	-8.1	-11.5	-13.2	13.5	15.2
Skill-intensive mfg	7.9	9.3	-7.6	-10.2	-11.5	-11.3	13.3	12.5
Skill-intensive services	1.8	3.3	-1.5	-5.4	-9.4	-12.6	11.0	14.6
Labour intensive srvices	4.3	3.0	-3.3	-4.6	-9.6	-9.3	11.3	10.4
GDP and export volume index	3.3	2.5	-2.8	-3.2	-9.3	-7.2	10.9	7.8

Source: Simulations of the dynamic model described in the text.

Table 10: Effects on Australian real 2030 export values of changes in global population scenario[a]

(Per cent departures from base line projections)

Product	(% departure from reference scenario)			
	Developing countries Low	Developing countries High	OECD[b] Low	OECD High
Paddy rice	-1.3	1.5	-9.9	11.9
Wheat	-9.0	11.6	-1.8	2.1
Other cereal grains	-7.6	8.5	-3.5	4.0
Vegetables, fruit and nuts	-15.2	21.7	-0.2	0.5
Oil seeds	-5.4	7.4	-7.7	9.2
Sugar cane, sugar beet	-7.9	9.6	-4.2	5.0
Plant-based fibres	-8.5	9.8	1.0	-1.1
Other crops	-5.9	8.9	-5.8	6.6
Cattle, sheep, goats and horses	-11.2	15.1	2.9	-2.6
Pig, poultry and other raw prod	-5.4	6.7	0.4	-0.3
Raw milk	-3.1	3.8	-2.5	3.1
Wool, silk-worm cocoons	-5.0	5.7	-1.2	1.2
Forestry	-17.6	24.0	-5.1	5.8
Fishing	-12.8	16.2	-6.7	7.8
Coal	-5.6	6.3	-3.6	3.7
Oil & gas	-9.5	11.6	-6.8	7.2
Minerals	-6.9	8.7	-1.7	2.2
Proc ruminant and horse prod	-1.9	2.4	-4.3	4.7
Proc pig, poultry and other meat	-2.6	3.2	-0.4	0.3
Vegetable oils and fats	-5.1	6.8	0.1	-0.1
Dairy products	-3.5	3.7	1.2	-1.4
Processed rice	-9.7	13.3	-0.4	0.9
Sugar	-4.7	6.6	-2.0	2.0
Other processed food products	-2.9	3.6	-0.8	0.6
Beverages and tobacco products	2.6	-3.3	2.0	-3.4
Other labour-intensive manufactures	6.3	-7.3	0.9	-2.1
Skill intensive manufactures	2.3	-3.4	7.2	-7.8
Skill intensive services	3.6	-4.6	0.7	-1.9
Labour intensive services	2.7	-3.3	0.5	-1.6
All exports	-0.2	0.0	2.1	-1.9

a Real values are measured relative to the Australian GDP deflator

b including Former Soviet Union and Central Europe.

Table 11. Effects on Australian 2030 output and export volumes of changes in world population scenario[a]

(Per cent departures from base line projections)

Industry	% departure from reference or base line scenario							
	Developing countries low		**Developing countries high**		**OECD low**		**OECD high**	
	Output	**Exports**	**Output**	**Exports**	**Output**	**Exports**	**Output**	**Exports**
Paddy rice	-3.5	0.3	4.4	-0.7	-1.0	-10.3	1.4	11.9
Wheat	-6.1	-7.2	7.1	8.5	-1.7	-2.0	1.8	2.1
Other cereal grains	-1.4	-6.3	1.4	6.3	-0.6	-3.8	0.7	4.2
Vegetables, fruit & nuts	-4.0	-13.4	5.3	17.6	0.3	-0.7	-0.2	0.9
Oil seeds	-1.5	-3.6	2.1	4.7	-3.4	-8.0	3.9	9.1
Sugar cane, sugar beet	-1.4	-6.3	1.9	6.7	-0.8	-4.6	0.7	5.2
Plant-based fibres	-4.8	-6.0	4.7	5.9	0.5	0.5	-0.6	-0.7
Other crops	-1.5	-4.5	1.9	6.7	-0.2	-6.3	0.4	6.8
Cattle, sheep	-1.6	-10.0	2.0	12.6	-0.5	2.6	0.7	-2.3
Pig, poultry	-1.1	-4.4	1.3	5.1	0.5	0.0	-0.4	0.1
Raw milk	-0.7	-2.0	0.6	2.3	0.8	-3.0	-0.8	3.4
Wool, silk-worm cocoons	-1.6	-3.4	1.4	3.4	-0.3	-1.5	0.3	1.4
Forestry	0.2	-18.4	-0.1	24.3	1.5	-7.4	-1.4	8.1
Fishing	-2.2	-11.8	2.6	14.0	-0.5	-6.9	0.8	7.5
Coal	-1.0	-2.5	1.0	2.6	-0.4	-2.1	0.4	2.0
Oil and Gas	-0.8	-6.8	0.9	7.6	0.1	-7.1	0.0	7.2
Minerals	-1.3	-5.8	1.5	7.0	0.9	-3.1	-0.7	3.4
Ruminant meats	-0.4	-1.3	0.5	1.5	-2.0	-4.8	2.2	5.0
Pig, poultry meats	0.1	-1.8	-0.1	2.0	0.7	-0.9	-0.6	0.7
Vegetable oils and fats	-0.5	-5.1	0.7	6.5	1.6	-0.2	-1.5	0.3
Dairy products	-1.0	-3.1	1.0	3.0	0.9	1.1	-0.9	-1.2
Processed rice	-4.5	-9.2	5.8	11.9	0.4	-0.6	-0.2	1.0
Sugar	-2.0	-4.1	2.7	5.5	-0.8	-2.1	0.7	2.1
Other processed foods	-0.5	-2.9	0.7	3.5	0.3	-1.1	-0.3	0.9
Beverages and tobacco products	0.6	2.7	-0.7	-3.3	1.1	2.0	-1.2	-3.2
Labour-intensive mfg	2.4	6.0	-2.7	-6.6	2.8	0.3	-2.6	-1.5
Skill-intensive mfg	2.1	2.3	-2.5	-3.3	5.6	6.9	-5.4	-7.2
Skill-intensive services	0.2	3.2	-0.2	-4.0	1.6	0.2	-1.3	-1.3
Labour intensive srvices	0.5	2.4	-0.5	-2.9	3.5	0.7	-2.9	-1.6
GDP and export volume index	0.5	0.5	-0.5	-0.8	-1.5	2.0	-2.4	-2.4

Source: Simulations of the dynamic model described in the text.

Appendix

This appendix includes a brief explanation of how the annual growth rates of regional population are constructed based on the stochastic population forecasts interpreted by Duncan and Wilson (2004). It then discusses how the growth rates of skilled and unskilled labour are calculated for each region, in line with our assumptions and the growth rates of the population. At the end of the appendix, we also include some information of the reference simulation.

A1. Construction of the Annual Growth Rate of the Regional Population

A1.1 The Source Data

The major source of population forecasts are those described in Duncan and Wilson (2004). These forecasts include the median of total population for 13 regions in the world, as well as the confidence intervals of these forecasts. The 13 regions are listed as follows:

Former Soviet Union
Eastern Europe
Western Europe
PacificOECD
Pacific Asia
China & CPA
South Asia
Middle East
Central Asia
Latin America
North America
Sub Saharan Africa
North Africa

The forecasts are for the 2000-2030 period, with 5-year intervals.

A1.2 Regional Mach

To match the 13 regions of population forecast to the 14 regions of our interest in the population project, we use the following approaches:

1) Direct match: 4 regions can be matched directly: North America, Latin America, Sub Saharan Africa, and Western Europe;
2) Weighted Average: In 2 cases, the region of our interest is composed of two regions with the population forecast. We use the weighted average growth rate of the two regions as the growth rate of the region in this study. The weight we choose is the population share of the region. By this approach, we construct

growth rates of Middle East & North Africa, and of Central Europe & Former Soviet Union.

3) Use the regional forecast for individual countries within the region: there are no separate population forecasts for 6 of the 14 regions of our interest. However, there are forecasts of the broader area where these countries/regions are located. We use the same forecast of the broader areas for each country/region within the area. For example, the population forecasts for India and Other South Asia are identical,
4) Other: there is no separate forecast for Australia in these set of forecasts. We use the information provided by Heather Booth (2002), a demographer at Research School of Social Sciences at the ANU.

A1.3. Calculating Annual Growth Rate

The annual growth rate between 2000 and 2030 is calculated in two steps. The first step is to calculate the annual growth rate for each 5-year interval, assuming that the growth rate is constant during the 5-year period. In the second step, we assume that the annual growth rate declines/increases at a constant rate, and work out the growth rate for each year between 2000 and 2030. Finally, we extrapolate the growth rate for 1998-2000 when no data is available form these set of forecasts.

A2. Construction of Annual Growth Rates of Skilled and Unskilled Labour

The annual rate of growth of skilled and unskilled labour is constructed so that: (1) the annual growth rate of the labour force is the same as that of the population of the region; (2) the ratio of skilled labour to the labour force increases at an constant rate and it reaches the target ratio by 2030. Both considerations are based on the assumptions we make for the simulation. The first one essentially assumes that participation rate is constant over time, and thus the growth rate of labour force and that of the population is identical. The second one assumes that the skilled labour/labour force ratio in each region rises over time as the economies grow. The set of the target ratios by 2030 is listed in Table A1. These ratios are chosen to be in consistent with the projections of other studies (for instance, Walmsley, Dimaranan and McDougall 2000).

Table A1 also lists the skilled labour/labour force ratios in 1995, which are based on Table A3.2 in. WorldScan—the Core Version (CPB 1999). We use these as the initial values of skilled labour/labour force ratio. Assuming these initial ratios increase smoothly (the annual change of the ratio is the same for each year) until they reach the target ratios in 2030, we construct the skilled labour/labour force ratio of each year for each region.

It is now quite straightforward to find the annual growth rate of skilled labour, given the growth rate of the labour force and the skilled labour/labour force ratios. The growth rate must be such that the skilled labour grows sufficiently to achieve the pre-determined share of skilled-labour in the labour force.

Table A1. The Target Ratio of Skilled labour/Labour Force for each Research

Region	2030 (target ratio)	1995
North America	0.45	0.36
South America	0.4	0.18
Sub-Saharan Africa	0.15	0.04
Middle-East and North Africa	0.35	0.14
West Europe	0.45	0.36
Central/East Europe and FSU	0.45	0.36
India	0.25	0.12
Other South Asia	0.25	0.12
Japan	**0.45**	0.36
China	**0.30**	0.16
Indonesia	0.40	0.2
Other East and SE Asia	0.45	0.2
Australia	**0.45**	0.36
Rest of world	0.27	0.2

Once the growth rate of the skilled labour is determined, the growth rate of the unskilled labour can be calculated using equation (A1):

$$S_{SKL} * g_{SKL} + S_{USKL} * g_{USKL} = g_{LAB} \quad \text{(A1)}$$

where 's' and 'g' is for the share of skilled/unskilled labour in labour force, and for the growth rate of skilled/unskilled and total labour forces, respectively, while the subscript 'SKL' and "USKL' is for skilled labour and unskilled labour, respectively.

The growth rates of skilled/unskilled labour derived above are for the reference simulation. We also need to construct the growth rates for the policy shocks to examine the impact of various population/labour force growth scenarios. Since we know the upper/lower band of the 95% confidence interval of population/labour force from the population forecast, and we know the share of skilled labour in labour force for each year, we simply use the same approach as we just explained to construct the growth rates of skill/unskilled labour force for each scenario.

Table A2: Region-generic elasticities of substitution between domestic and imported goods

Commodity or product	Elasticity
Paddy rice	2.2
Wheat	2.2
Other cereal grains	2.2
Vegetables, fruit and nuts	2.2
Oil seeds	2.2
Sugar cane, sugar beet	2.2
Plant-based fibres	2.2
Other crops	2.2
Cattle, sheep, goats and horses	2.8
Pig, poultry and other raw prod	2.8
Raw milk	2.2
Wool, silk-worm cocoons	2.2
Forestry	2.8
Fishing	2.8
Coal	2.8
Oil & gas	2.8
Minerals	2.8
Proc ruminant and horse prod	2.2
Proc pig, poultry and other meat	2.2
Vegetable oils and fats	2.2
Dairy products	2.2
Processed rice	2.2
Sugar	2.2
Other processed food products	2.2
Beverages and tobacco products	3.1
Other labour-intensive manufactures	3.0
Skill intensive manufactures	2.8
Skill intensive services	2.0
Labour intensive services	1.9

Source: GTAP Version 5 Data Base.

Table A3: Region-generic elasticities of substitution among value-added component, and among intermediate inputs in production

Commodity or product	Elasticity of substation between labour, capital and land	Elasticity of substitution among composite intermediate inputs
Paddy rice	0.2	0.5
Wheat	0.2	0.5
Other cereal grains	0.2	0.5
Vegetables, fruit and nuts	0.2	0.5
Oil seeds	0.2	0.5
Sugar cane, sugar beet	0.2	0.5
Plant-based fibres	0.2	0.5
Other crops	0.2	0.5
Cattle, sheep, goats and horses	0.2	0.5
Pig, poultry and other raw prod	0.2	0.5
Raw milk	0.2	0.5
Wool, silk-worm cocoons	0.2	0.5
Forestry	0.2	0.5
Fishing	0.2	0.5
Coal	0.2	0.5
Oil & gas	0.2	0.5
Minerals	0.2	0.5
Proc ruminant and horse prod	1.1	0.5
Proc pig, poultry and other meat	1.1	0.5
Vegetable oils and fats	1.1	0.5
Dairy products	1.1	0.5
Processed rice	1.1	0.5
Sugar	1.1	0.5
Other processed food products	1.1	0.5
Beverages and tobacco products	1.1	0.5
Other labour-intensive manufactures	1.3	0.5
Skill intensive manufactures	1.3	0.5
Skill intensive services	1.3	0.5
Labour intensive services	1.5	0.5

Source: GTAP Version 5 Data Base.