Global Population Forecast Errors, Economic Performance and Food Demand: Preliminary Simulations*

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Paper for presentation at the 46th Annual Conference of the Australian Agricultural and Resource Economics Society, Canberra, 13-15 February 2002.

*Funding for this research is via a grant from the Rural Industries Research and Development Corporation to address "Global Demographic and Income Trends: Their Implications for Food Consumption". Thanks are due to Ron Duncan, Robert McDougall and Terry Walmsley for useful discussions and assistance.

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Abstract:

The recent analysis of global population forecasts of the past 30 years by the US National Academy of Sciences (Bongaarts and Bulatao, 2000) confirms that errors have been considerable and that population forecasts have generally been upward-biased. We adapt a standard global economic model to estimate the implications of the global and regional population forecast errors suggested by this study, via their demographic and income effects, for the performance of the global economy and the composition of global food demand. The model is "GTAP-Dyn", a recursively dynamic, applied general equilibrium model of the world economy (Ianchovichina and McDougall, 2000). The results indicate that slower than forecast population (and hence labour force) growth causes slower growth in Australia's overall economy and in its agricultural, food and minerals sectors in particular. When the population growth slowdown is restricted to developing countries, the overall effects on Australia are smaller but there is a substantial reallocation of resources away from agriculture, food production and other natural resource based industries in favour of manufactures.

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. In this paper we focus on population size and the potential impact of forecast errors in population size on economic forecasts and thereby in projections of the composition of final demand.

A useful starting point is the aggregated analysis of population forecasts carried out recently by the US National Academy of Sciences (Bongaarts and Bulatao, 2000). This study establishes clearly that global population forecasts of the past three decades have tended to underestimate the declines in fertility that are part of the final phase of the demographic transition. As a consequence, they have overestimated future population growth rates. UN estimates of global population have been in error by as much as four per cent. Errors in forecasts of country and regional populations, however, have been much larger: up to 17 per cent over 30 years. Because of the low quality of demographic data in some developing countries, errors in forecasting

developing world populations are much larger than those in forecasts of the richer, better recorded, countries.

To address the economic implications of the population forecast errors highlighted by Bongaats and Bulatao, we employ a standard long-term dynamic model of the world economy, namely GTAP-dyn (Ianchovichina and McDougall, 2000). Its structure enables us to capture the aggregate Engel effects on food consumption demand emphasised by Coyle et al. (1998) and Gehlhar and Coyle (2001) and to do so at a high level of country and commodity disaggregation. We are therefore able to assess the effects of changes in international income inequality on the demand for inferior and income-elastic products. When these effects are properly accounted for the results suggest that forecasts of global demand for staple cereal products, such as those by the IFPRI (1995, 1996), are overstated.

Yet, for examining the effects of long-term demographic changes on the composition of demand, GTAP-Dyn has a major weakness. It includes only a single representative household in each identified region. Each region's population and labour force is projected exogenously at constant growth rates. In the current version, changes in age and income distributions cannot, therefore, be represented, nor can their influence on food demand be analysed. In this paper we do not modify the model to address these issues. [1] We focus, instead, on the role of aggregate population 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.

1. Errors in population forecasts:

The principal source of errors in past population forecasts was 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 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.

[1] To address these issues in our on-going research we propose to modify GTAP-Dyn to include multiple households within each region and multiple age groups within each household. The households would be distinguished by the composition of their income, which can originate from capital, land and resource rents and the wages of raw labour and skill. Within each household the age distribution would also be crudely represented.

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.[2] 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. In this preliminary analysis, we make an extreme interpretation of these past errors. We make a 15-year forecast, based in 1995 and extending through 2010. We then modify this forecast in two alternative ways:

1) The mean absolute error for 15-year forecasts is found by Bongaarts and Bulatao to be approximately 10 per cent. This is equivalent to a difference in growth rate of 0.64 per cent per year. Our first counterfactual analysis is then constructed by having all regions in the world experience population and labour force growth that is smaller by this amount.
2) To examine the effects of comparatively large population forecast errors in developing countries, we construct a second counterfactual analysis based on the assumption that errors only occur in developing country population forecasts and that the effect of these is to cause overestimation by 1.1 per cent per year. In this scenario, then, the 2010 populations and labour forces of developing regions are lower by 15 per cent.

2. The Prototype economic model

To analyse the implications of both demographic and income changes for the composition of global food demand we have adapted the "GTAP-Dyn" model. It is a recursively dynamic applied general equilibrium model of the world economy that extends the standard comparative static GTAP model of Hertel (1997). This model offers a more complete characterisation of international capital mobility, capital accumulation and investment than the comparative static original. And these additions are necessary in order to offer a better analysis of long run trends than the original comparative static framework was capable of. The model covers up to 65 countries and regions of the world and enables the analysis of world markets for the agricultural and food products listed in Table 1, which are part of an economy-wide

[2] See Bongaarts and Bulatao (2000), Figure 2-3.

product list of 54. The analytical structure of GTAP-Dyn is described by Ianchovichina and McDougall (2000) and a recent application of an earlier version is Ianchovichina et al. (1998).

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 for the supply side of the model and these we adopt without modification.[3]

A key aspect of applications of the GTAP family of models is the choice of aggregation. Given our focus on 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.[4] 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. The country groups chosen, and their composition, are detailed in the Appendix.

3. Results from preliminary simulations

The approach adopted is, first, to construct a reference, or base, scenario for the world economy over the period 1996-2010. Two further simulations are then constructed that differ from the reference one only in that the exogenous growth rates of populations and labour forces differ as indicated in Section 1.

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. In our preliminary simulations we have chosen a level of international capital mobility that is at the low end of those available in the model. Sensitivity to this choice is likely to be considerable and we will explore it quantitatively in future papers.

[3] 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).
[4] The model, as currently constructed, runs on the GTAP Version 4 global database for 1995. The more recent, and more extensive, Version 5 database, for 1997, is as yet incompatible with GTAP-dyn.

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. 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 the subsequent counterfactual simulations, 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 population growth. The effects on forecast GDP and GDP per capita are indicated in Table 2.

It is clear that slower population growth slows the growth in GDP, through the mechanism of slower labour force growth. When the slower population growth is restricted to the developing countries, however, there are also small effects on the economic performance of the industrial regions. The magnitudes of these depend on how the international terms of trade is affected. As simulated, they are too small to show up at the two significant figure level displayed in the table. Finally, when population growth slows, because labour is only one of many factors of production income generation does not slow to the same extent. So income per capita grows more rapidly.[5]

Reference scenario:

The reference scenario presented remains less than satisfactory for our purpose. With the low level of international capital mobility assumed, capital accumulation in the poorer but rapidly growing countries (China and the other Asian regions in particular) is slower than expected. To achieve the exogenously imposed growth targets (indicated in Table 2) the implied productivity gains are above historical experience and, in some cases, quite unrealistic. One consequence of this is that, since these productivity gains are distributed uniformly across all industries, agricultural production is raised more than might reasonably be anticipated. The general effect of this is to cause the developing countries to experience substantial real depreciations against the industrialised economies. More specifically, high food production in these very large developing countries depresses world food prices. The

[5] Or, as in the cases of Sub-Saharan Africa, North Africa and the Middle East, income per capital contracts more slowly.

pattern of this effect is illustrated in Figure 1. Grains, marine products and fibres are most seriously affected. Their international prices decline more than is anticipated.

The counterfactual scenarios:

In the case where there is a uniformly slow rate of global population growth, Australia is adversely affected not only by the lower trajectory of its own labour force but also by the relative decline in demand for its products abroad. This is clear from Figure 2. In this scenario, slower growth everywhere not only weakens the industrial economies but, because the productivity forecasts are larger for the developing countries there is a tendency for their real depreciations against the industrial countries to be larger, exacerbating the downward pressure on Australian export prices. When the population growth is slower only in the developing countries, their comparative labour abundance is reduced and their costs are raised relative to the industrial countries, so their real depreciations are greatly reduced. This effect offsets the tendency for slower developing country growth to reduce global aggregate demand and hence to lower Australian export prices.

The relative price effects of the two counterfactual scenarios are summarised in Table 3. Consistent with Figure 2, the Australian economy is hardest hit by the reduction in global population growth. In that case all export commodities have lower prices relative to the GDP deflator (that is, relative to other importable or non-traded Australian products). Worst hit is the mineral and energy sector, while manufacturing and tradeable services industries are advantaged. Agricultural products fare slightly better than average (in particular, better than minerals and energy) but their relative prices decline, the largest relative declines being in cereals, fibres and forestry products. When the slower population growth is restricted to developing countries, on the other hand, as expected from Figure 2, the relative price changes are much smaller. There is reduced competition from developing countries in this scenario and, even though the minerals and energy sector is adversely affected, the relative prices of agricultural and manufactured products actually increase.

The corresponding pattern of changes to the volumes of output and exports in Australia is given in Table 4. Once again, when the population slowdown is global not only is aggregate demand reduced at home and abroad but also Australia's real appreciation against the developing countries is larger. These forces reduce the growth in both output and exports substantially. Although the variation in output

across sectors is not large, that in export volumes is considerable, with forest products, minerals and energy and sugar being worst affected.

When the population slowdown is only in the developing countries, the global pattern of comparative advantage is altered considerably. Australian food and agricultural production is smaller and its exports of these products are considerably smaller. The production and export of manufactures expands, however, as less populated developing countries lose their comparative advantage in manufacturing. The variation in effects on Australian commodity exports is considerable. The largest reductions are in forest products, cereal grains, cattle and sheep meats and sugar.

Finally, turning to the effects on factor owners in Australia, the results are shown in Table 5. Since the Australian economy is worst affected by a uniform slowdown in global population growth, average primary factor returns (measured relative to consumer prices) must fall most in this case. And this is clear from the very large fall in real returns to natural resources, land and physical capital. Real wages of both unskilled and skilled workers rise, however, in this scenario. This is because Australia, too, has lower population and labour force growth. Indeed, Australia's population in 2010 is projected to be smaller in this scenario by nine per cent. Comparatively speaking, this represents a contraction in Australia's labour supply and hence there follow rises in its forecast real wage levels.

When the slower population growth is restricted to developing countries the contraction in Australia's economy is small and the changes in its factor returns are also modest. They are least for unskilled and skilled labour because the shock to the world economy is a reduction in its labour force. This must raise wages relative to other factor returns even in countries like Australia that are only indirectly affected by the shock. The return on natural resources is, once again, most adversely affected by the slower developing country growth.

4. Conclusion:

Demographic shocks are shown to affect the Australian economy significantly when its labour force is affected and when aggregate demand in other industrial countries falls. But the effects are modest when the demographic shocks are to developing countries alone. Nonetheless, the sectoral implications of a slowdown in developing country population growth are significant over a 15-year forecast period. It causes a substantial reallocation of resources within the Australian economy away

from the food, agricultural and minerals sectors and toward manufacturing. Factor returns to land and other natural resources grow more slowly in that case.

These results are very preliminary and serve to illustrate the early products of this research only. Further work to adapt the dynamic model used to analyse demographic shocks is required as the project unfolds.

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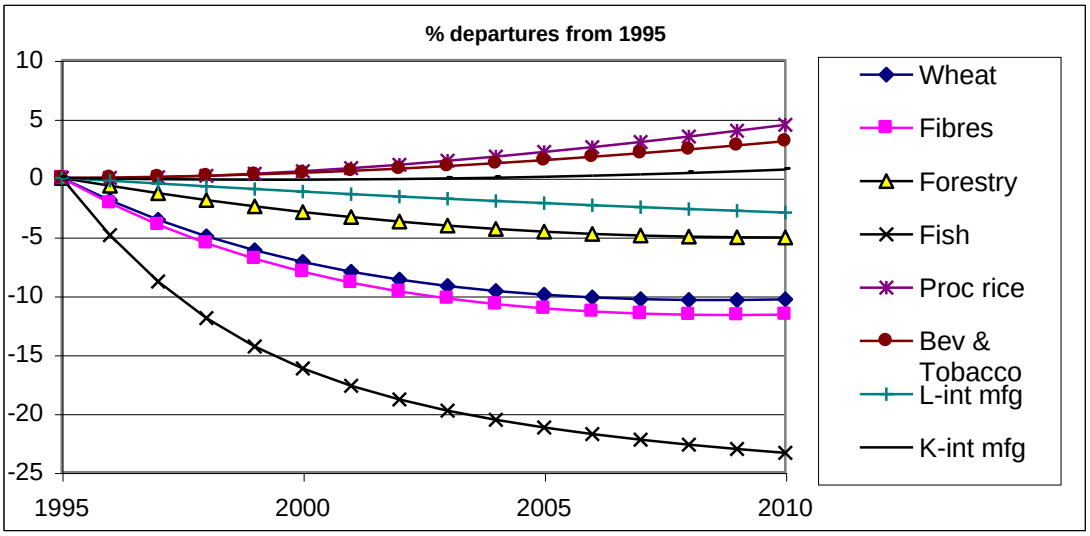
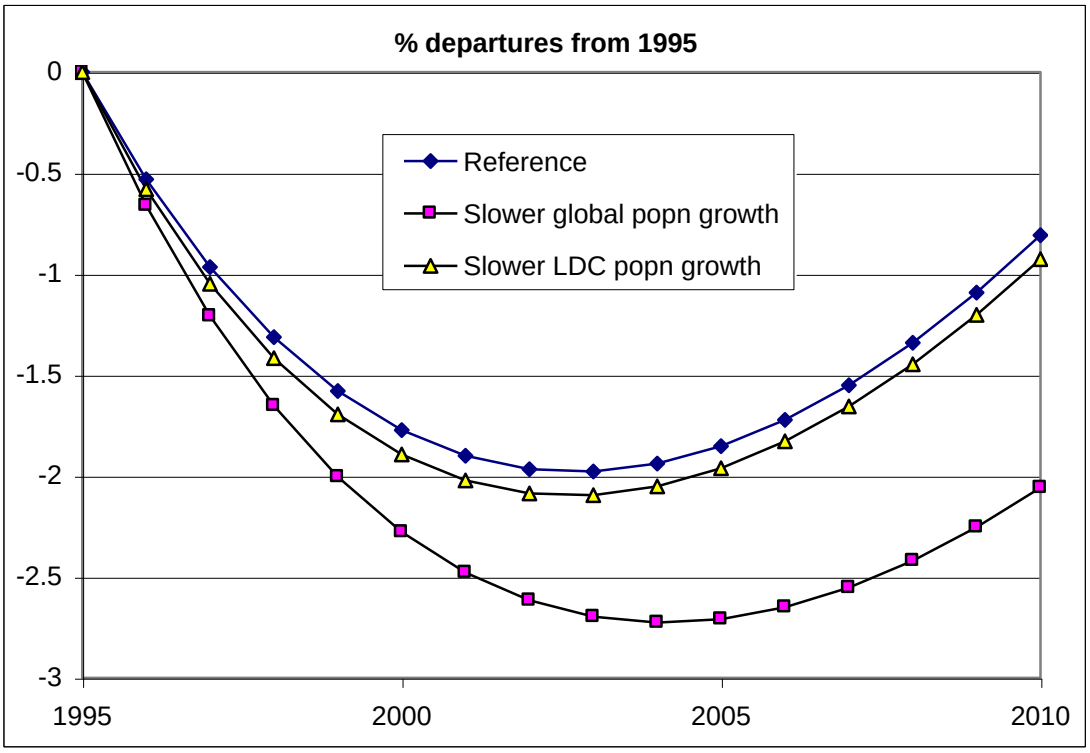
Figure 1: Selected real Australian export prices, reference scenario[a]



a Export prices relative to the Australian GDP deflator.
Source: Simulations of the dynamic model described in the text.

Figure 2: Index of real Australian export prices[a]



a Export value weighted index measured relative to the Australian GDP deflator.
Source: Simulations of the dynamic model described in the text.

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

Source: GTAP Version 4 Data Base. The full commodity list covers 54 products in all, of which the majority are manufactures and services.

Table 2: Simulated population, GDP and GDP per capita growth rates, 1995-2010

Country/region	Population growth rate[a]			GDP growth rate			Growth rate of GDP per capita		
	Reference	Slower global population growth	Slower population growth in developing countries	Reference[a]	Slower global population growth[b]	Slower population growth in developing countries[b]	Reference	Slower global population growth[b]	Slower population growth in developing countries[b]
North America	1.3	0.6	1.3	3.5	3.1	3.5	2.2	2.5	2.2
South America	1.5	0.9	0.4	1.0	0.7	0.5	-0.5	-0.1	0.1
Sub-Saharan Africa	2.5	1.9	1.4	0.5	0.2	-0.1	-2.0	-1.7	-1.5
Middle-East and North Africa	1.9	1.3	0.8	0.5	0.3	0.1	-1.4	-1.0	-0.7
West Europe	0.3	-0.3	0.3	3.0	2.5	3.0	2.7	2.9	2.7
Central/East Europe and FSU	-0.2	-0.8	-0.2	4.0	3.6	4.0	4.2	4.4	4.2
India	2.0	1.4	0.9	5.0	4.6	4.4	3.0	3.3	3.5
Other South Asia	1.4	0.7	0.2	7.0	6.6	6.4	5.6	5.9	6.1
Japan	0.1	-0.5	0.1	0.5	0.1	0.5	0.4	0.6	0.4
China	0.9	0.3	-0.2	8.0	7.6	7.3	7.1	7.3	7.5
Indonesia	1.8	1.2	0.7	6.0	5.7	5.4	4.2	4.5	4.7
Other East and SE Asia	1.6	1.0	0.5	2.0	1.7	1.5	0.4	0.7	1.0
Australia	1.2	0.5	1.2	4.0	3.6	4.0	2.8	3.1	2.8
Rest of world	1.9	1.2	0.8	3.0	2.7	2.4	1.1	1.4	1.7

a Exogenous.

b Endogenous, given productivity growth implied in the reference scenario.

Source: Exogenous growth rates are from sources discussed in the text. Endogenous rates are simulated using the model discussed in the text.

Table 3: Effects on Australian real 2010 export prices of changes in global population scenario[a]

(% departure from reference scenario)

Product	Slower global population growth	Slower population growth in developing countries
Paddy rice	-1.01	0.11
Wheat	-1.09	0.03
Other cereal grains	-1.05	0.09
Vegetables, fruit and nuts	-1.01	0.13
Oil seeds	-1.04	0.11
Sugar cane, sugar beet	-1.01	0.07
Plant-based fibres	-1.05	0.11
Other crops	-0.99	0.13
Cattle, sheep, goats and horses	-0.99	0.10
Pig, poultry and other raw prod	-0.83	0.12
Raw milk	-1.00	0.08
Wool, silk-worm cocoons	-0.99	0.10
Forestry	-1.12	0.25
Fishing	-0.32	0.75
Minerals and energy	-4.75	-1.08
Proc ruminant and horse prod	-0.30	0.15
Proc pig, poultry and other meat	-0.41	0.11
Vegetable oils and fats	-0.57	0.15
Dairy products	-0.94	0.01
Processed rice	-0.91	0.06
Sugar	-0.58	0.13
Other processed food products	-0.19	0.18
Beverages and tobacco products	-0.90	0.05
Other labour-int manufactures	0.16	0.44
Skill intensive manufactures	-0.47	0.22
Skill intensive services	0.95	0.30
Labour intensive services	-0.18	0.09
Export price index rel to GDP deflator	-1.25	-0.12

a Real prices are measured relative to the Australian GDP deflator.
Source: Projections using the dynamic model described in the text.

Table 4: Effects on Australian 2010 output and export volumes of changes in global population scenario

Industry	% departure from reference scenario			
	Slower global population growth		Slower population growth in developing countries	
	Output	Exports	Output	Exports
Paddy rice	-11	-15	-4	-19
Wheat	-12	-13	-9	-15
Other cereal grains	-11	-13	-3	-13
Vegetables, fruit and nuts	-11	-9	-2	-7
Oil seeds	-11	-8	-3	0
Sugar cane, sugar beet	-13	-15	-9	-14
Plant-based fibres	-8	-7	-2	-6
Other crops	-10	-9	-2	-5
Cattle, sheep, goats and horses	-11	-9	-2	-16
Pig, poultry and other raw prod	-10	-7	-1	-1
Raw milk	-10	-11	-2	-1
Wool, silk-worm cocoons	-8	-7	-2	-3
Forestry	-9	-23	0	-27
Fishing	-12	-17	-1	-7
Minerals and energy	-11	-13	-5	-9
Proc ruminant and horse prod	-11	-12	-1	-2
Proc pig, poultry and other meat	-11	-9	0	-3
Vegetable oils and fats	-11	-14	-2	-17
Dairy products	-10	-8	-2	-7
Processed rice	-11	-10	-6	-13
Sugar	-11	-11	-4	-7
Other processed food products	-11	-10	0	-2
Beverages and tobacco products	-11	-8	0	6
Other labour-int manufactures	-9	-6	4	8
Skill intensive manufactures	-8	-4	2	3
Skill intensive services	-13	-12	0	5
Labour intensive services	-10	-5	0	2
GDP and export volume index	-11	-8	0	-1

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

Table 5: Effects on Australian 2010 real factor rewards of changes in global population scenario[a]

(% change relative to the reference scenario)

	Slower global population growth	Slower population growth in developing countries
Land	-6.9	-1.5
Labour	4.6	-1.2
Skill	5.1	-1.1
Physical capital	-7.8	-1.6
Natural resources	-20.3	-8.4

a Real rewards are measured relative to the Australian CPI or consumption price index.
Source: Simulations of the dynamic model described in the text.