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How would global trade liberalization affect rural and regional incomes in Australia?

Kym Anderson, James Giesecke and Ernesto Valenzuela[†]

Agricultural protection in rich countries, which had depressed Australian farm incomes via its impact on Australia's terms of trade, has diminished over the past two decades. So too has agricultural export taxation in poor countries, which has had the opposite impact on those terms of trade. Meanwhile, however, import protection for developing country farmers has been steadily growing. To what extent are Australian farmers and rural regions still adversely affected by farm and non-farm price- and trade-distortive policies abroad? This paper draws on new estimates of the current extent of those domestic and foreign distortions: first, to model their net impact on Australia's terms of trade (using the World Bank's Linkage model of the global economy); and second, to model the effects of that terms of trade impact on output and real incomes in rural versus urban and other regions and households within Australia as of 2004 (using Monash's multi-regional TERM model of the Australian economy).

Key words: regional CGE modelling, rural income, trade liberalization.

1. Introduction

Throughout the post–World War II period, Australian farmers have been discriminated against by policies at home and abroad. At home, Australia's manufacturing protection policies far more than offset the country's agricultural support policies, so the farm sector and farm household incomes were smaller than they would have been without those policies; but domestic reforms in the past three decades have virtually removed that part of the discrimination (Anderson *et al*. 2007). Abroad, the Australian farm sector was an indirect beneficiary, through improved terms of trade, of anti-agricultural policies of developing countries such as export taxes, but had been harmed by pro-agricultural policies in other high-income countries (Tyers and Anderson 1992). Over the past quarter-century the former have greatly diminished, and even the latter have diminished somewhat in their trade impact. Nonetheless, those reforms have brought the world only about half way towards free merchandise trade, in terms of the effect of policies on global economic welfare (Valenzuela *et al*. 2009).

[†] Kym Anderson (e-mail: kym.anderson@adelaide.edu.au) is the George Gollin Professor of Economics, University of Adelaide, Adelaide, South Australia 5005, Australia. James Giesecke is at the Centre of Policy Studies, Monash University, Clayton, Victoria 3800, Australia. Ernesto Valenzuela is at the School of Economics, University of Adelaide, Adelaide, South Australia 5005, Australia.

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What would be the impact of removing those remaining distortions in world markets for goods on farm versus non-farm incomes and on rural versus other areas in Australia? To answer this question, the present paper draws on new estimates of the current extent of those domestic and foreign distortions first to model their net impact on Australia's terms of trade (using a model of the global economy), and second to model the effects of that terms of trade impact on rural vs urban and other regions and households within Australia as of 2004 (using a multi-regional model of the Australian economy).

The Australian case is different from that of other high-income countries in at least two respects. First, agriculture has never been assisted more than non-agricultural sectors in Australia, in contrast to virtually all other Organization for Economic Cooperation and Development (OECD) countries. In that sense, it is much more like a primary product-exporting developing country. And second, since the mid-1970s Australian exports of minerals and energy raw materials have been indirectly assisted by quotas on petroleum production (agreed to by members of OPEC, the Organization of the Petroleum Exporting Countries). Hence, sectoral policies abroad hurt Australian farmers and rural areas not only relative to urban areas but also relative to (mainly remote) areas specializing in mining. OPEC's policy of output restraint is not (yet) subject to negotiation at the World Trade Organization (WTO), so has to be accepted as is rather than be treated as a policy amenable to reform. Agricultural policies, on the other hand, are an integral part of the WTO's current round of multilateral trade negotiations and so in principle are subject to reform. Hence, information on their effects is valuable in that it can be used to generate support for policy reform.

Past studies have provided information on the effects of agricultural and trade policies on the farm sector and overall economy nationally (e.g., Anderson and Martin 2006), but to our knowledge there have been no studies prior to the present one that have shown their effects regionally. Yet the degree of price distortion varies hugely between products and hence can be expected to affect regions differentially according to their commodity specializations.[1]

The paper is organized as follows. We begin by describing the two-stage modeling approach used to estimate first the net impact on Australia's terms of trade of distortions to agricultural and other goods markets abroad as of 2004 and then the regional and net farm vs nonfarm income consequences of those terms of trade effects. We then discuss model results. They reveal that the removal of world agricultural and other goods trade distortions would have a positive impact on rural regions, a negative impact on mining-intensive regions, and mixed for urban regions. While the growth of agricultural protection in rich countries has reversed a little recently, developing countries

[1] This approach to examining the impact of foreign policies on different regions and households within a national economy, by using the combination of a global model and a compatible national model, will have ever-more applications as globalization proceeds. An obvious example is the impact of climate change and responses to it by the rest of the world.

as a group have transitioned from effectively taxing their farmers to assisting them relative to their manufacturers, particularly via food import restrictions (Anderson 2009). If this trend continues, Australian farmers and rural regions will have even more reason to press for an ambitious reform outcome from the agricultural part of the multilateral trade negotiations under the WTO.

2. Modeling approach

To get a sense of just how much agricultural and trade policies abroad are impacting on farmers and others in Australia, a two-stage modeling procedure is needed. For the first stage, we use a global model to estimate the net impact on Australia's terms of trade of distortions to agricultural and other goods markets abroad in 2004 (known as the Linkage Model, described in van der Mensbrugghe 2005). For the second stage, a national model with regional details (known as the TERM (The Enormous Regional Model), described in Horridge *et al.* 2005) is used to estimate the regional consequences of the terms of trade effects of those discriminatory policies. Since Australia had virtually no farm or industrial sector distortions of its own by 2004, there is no need to also simulate own-country reform.

2.1. The global (Linkage) model

Global results, based on the comparative static version of the Linkage model, use a modified version of the latest pre-release of the Version 7 database of the Global Trade Analysis Project (Narayanan and Walmsley 2008). That database is modified in the sense that the distortions to developing country agriculture are replaced with ones from the World Bank's new estimates of distortions to agricultural incentives (Anderson and Valenzuela 2008; expressed as an alternative set of price distortions for using in CGE models by Valenzuela and Anderson 2008). These simulated global results (see Anderson *et al.* 2010b) are transmitted to the Australian national model via changes in the vectors of import prices and export demands. The latter are implemented as vertical shifts in the export demand curves (that is, of the willingness to pay for Australian exports – see below).

2.2. The Australian (TERM) model

The national results use the Australian TERM model, which is a 'bottom-up' CGE model with features that enable it to deal with the detailed behavior of producers, consumers and government economic agents in many regions of the country. We simulate the impacts of the removal of current distortions to world markets on Australia by dividing the national economy into 59 regions (Statistical Divisions) and 27 industrial sectors. We also define three super-regions of urban, rural and mining localities, based on the ratio of the sectoral value-added share for each region to the national share of sectoral value added (see Appendix Tables A1 and A2 for the regional and sectoral classifications and the regions' relative sectoral value-added shares). The 13 urban regions comprise just over 73 per cent of the population and 71 per cent of national Gross Domestic Product (GDP), and the 13 mining regions comprise 9 per cent of the nation's population and 13 per cent of GDP. Thus, the 33 rural regions account for the residual 18 per cent of the population and 16 per cent of GDP.

The data structure in TERM allows the model to capture explicitly the behavior of industries, households, investors, exporters and the government all at the regional level. The model's theoretical structure is based on that of the well-known CGE model, ORANI (Dixon *et al.* 1982). Producers in each regional industry are assumed to maximize profits subject to a production technology that allows substitution between primary factors (labor, capital and land) and between geographical sources of supply for intermediate inputs. A representative household in each region purchases goods to obtain the optimal bundle in accordance with its preferences and its disposable income. Investors seek to maximize their rate of return. In the short-run, this desire is expressed as a positive relationship between regional industry investment and rates of return, but in the medium- to long-run assumed here it is expressed as the endogenous physical capital supply to each regional industry at exogenous rates of return.

Commodity demands by foreigners are modeled via export demand functions that capture the responsiveness of foreigners to changes in Australian supply prices. Economic agents decide on the geographical source of their purchases according to relative prices and a nested structure of substitution possibilities. The first choice facing the purchaser of a unit of a particular commodity is whether to buy one that has been imported from overseas or one that has been produced in Australia. If an Australian product is purchased, a second decision is made as to the particular region the commodity originates from. It is assumed that Australian-made brands are considerably more substitutable than is an Australian brand with a foreign brand. The national data include regional margins for transportation and retailing, with the possibility of substitution of the margins sources based on their relative prices.

2.3. Simulation design

Terms of trade results are available, for a wide range of countries, from the World Bank's LINKAGE model under a long-run scenario in which world agricultural and other goods market distortions as of 2004 are removed (van der Mensbrugghe *et al.* 2010). The first three columns of Table 1 report comparable results for Australia. To use the TERM model to assess the implications of that set of price impacts at Australia's national border for various sectors and regions of its economy, we translate into TERM shocks the two sets of LINKAGE outputs: movements in foreign currency prices

Table 1 Impact of liberalizing rest of world's trade policies on prices and volumes of Australia's exports and imports (LINKAGE Model results, long-run percentage change relative to baseline)

LINKAGE Model commodity	Foreign currency export prices (1)	Export volumes (2)	Foreign currency import prices (3)	LINKAGE export demand elasticities (4)
Paddy rice	4.0	28.7	n.a.	6.2
Wheat	4.2	−7.9	n.a.	7.7
Other grains	4.3	29.1	n.a.	6.7
Oilseeds	4.3	−34.2	5.2	5.5
Sugar cane	n.a.	n.a.	n.a.	6.6
Plant-based fibres	4.2	27.6	−1.3	8.3
Vegetables and fruits	4.2	4.5	2.3	5.3
Other crops	4.2	0.4	1.2	5.5
Cattle sheep etc.	4.0	−7.9	8.3	5.2
Other livestock	4.0	−11.0	1.0	5.4
Raw milk	n.a.	n.a.	−1.3	5.5
Wool	4.2	10.9	10.0	3.7
Beef and sheep meat	3.3	59.3	11.2	5.4
Other meat products	3.2	19.4	0.6	5.0
Vegetable oils and fats	2.6	12.6	1.0	5.5
Dairy products	3.2	243.8	12.1	5.5
Processed rice	2.9	−3.2	3.6	6.1
Refined sugar	2.9	6.2	1.1	8.2
Other food, beverages and tobacco	2.7	54.7	3.4	5.4
Other primary products	2.6	−10.2	4.0	6.0
Textiles and wearing apparel	2.3	6.5	−0.3	5.7
Other manufacturing	2.3	−6.5	0.1	5.7
Services	2.6	−10.9	−0.3	2.9

Source: Authors' calculations using the LINKAGE Model, from van der Mensbrugghe *et al*. (2010).

for Australian imports, and vertical movements in foreign demand schedules for Australian exports.

For movements in foreign currency import prices, the communication of results between the two models is relatively straightforward. We translate movements in foreign currency import prices classified by LINKAGE commodity into movements in foreign currency import prices classified by TERM commodity via equation (1):

$$\left[\sum_{k\in Linkage} \mathrm{H}^{(\mathrm{M})}_{\mathrm{c,k}}\right] p^{(Term)*}_{(c,2)r} = \sum_{t\in Linkage} \mathrm{H}^{(\mathrm{M})}_{\mathrm{c,t}}\, p^{(Linkage)*}_{(t,2)} \; (c \in \mathrm{COM},\ r \in \mathrm{REG}) \quad (1)$$

where $\mathrm{H}^{(\mathrm{M})}_{\mathrm{c,k}}$ is a matrix of values showing the distribution of imports of TERM commodity c across LINKAGE commodities k; $p^{(Term)*}_{(c,2)r}$ is the percentage change in the foreign currency price of TERM commodity c used in region r; and $p^{(Linkage)*}_{t,2}$ is the percentage change in the foreign currency price of TERM commodity t (values for which are reported in column 3 of Table 1). Results for $p^{(Term)*}_{c,2}$ are reported in column 2 of Appendix Table A2.

Notice that in equation (1) the exogenous percentage movements in the foreign currency price of commodity c ($p_{(c,2)r}^{(Term)*}$) are assumed to be identical across all regions, a feature of our shocks that assists in the interpretation of regional results.

Translating LINKAGE results for foreign currency export prices into TERM shocks is more complicated. As Horridge and Zhai (2006) argue, the appropriate things to communicate to the national model are the willingness-to-pay shifts implicit in the price and quantity movements produced by the global model. Horridge and Zhai show that these can be calculated via the formula:

$$fp_t^{(Linkage)} = p_t^{(Linkage)*} + q_t^{(Linkage)*}/\eta_t^{(Linkage)} \tag{2}$$

where $fp_t^{(Linkage)}$ is the percentage vertical shift in the export demand schedule for LINKAGE commodity t; $p_t^{(Linkage)*}$ is the percentage change in the foreign currency export price for LINKAGE commodity t; $q_t^{(Linkage)*}$ is the percentage change in the quantity of exports of LINKAGE commodity t; and $\eta_t^{(Linkage)}$ is the export demand elasticity for LINKAGE commodity t. Unlike national models, where the export demand elasticity typically appears as an explicit parameter, in global models like LINKAGE, $\eta_t^{(Linkage)}$ is implicit in the theory and parameters governing how agents in each country substitute between alternative sources of supply for each commodity. We explain our method for calculating $\eta_t^{(Linkage)}$ in the Appendix. Column 4 of Table 1 reports our $\eta_t^{(Linkage)}$ estimates.

The results for $fp_t^{(Linkage)}$ are translated to vertical shifts for TERM commodities, $f_c^{(4)}$, via equation (3):

$$\left[\sum_{k\in Linkage} \mathrm{H}_{\mathrm{c,k}}^{(\mathrm{X})}\right] f_{c,r}^{(4)} = \sum_{t\in Linkage} \mathrm{H}_{\mathrm{c,t}}^{(\mathrm{X})}\, fp_t^{(Linkage)} \quad (c \in \mathrm{COM},\ r \in \mathrm{REG}) \tag{3}$$

where $\mathrm{H}_{\mathrm{c,k}}^{(\mathrm{X})}$ is a matrix of values showing the distribution of the value of TERM exports of commodity c across LINKAGE commodities k; $f_{c,r}^{(4)}$ is the vertical shift in the TERM export demand schedule for commodity c from region r; and $fp_t^{(Linkage)}$ is the vertical shift in foreign demands for Australian exports implicit in the LINKAGE simulation results reported in the first two columns of Table 1. Results are reported in column 1 of Appendix Table A2. Like equation (1), equation (3) assumes that the movements in commodity-specific export demand schedules ($f_{c,r}^{(4)}$) are identical across regions.

2.4. TERM model closure

Removal of distortions in global goods markets will have immediate impacts on rates of return, regional wage relativities and output prices. Our aim is to investigate the economic consequences of removing trade distortions after all market adjustments to these immediate policy-induced relative price changes have taken effect. That is, our concern is long-run. Hence, we use a standard long-run closure of TERM, which defines a long-run solution year with the following characteristics.

Investors in each industry in each region have had sufficient time to adjust regional industry capital stocks in response to the policy change. Thus, changes in demand for capital are manifest as changes in capital supply, not as changes in rental rates. We implement this by allowing capital to be in elastic supply to each regional industry at exogenous rates of return.

Most Australian regional jurisdictions enforce strict land clearance and native vegetation management regimes. We therefore do not allow the policy change to affect the long-run supply of agricultural land. Agricultural land supplies are thus exogenous, and land rental rates endogenously equate land supply and demand.

We assume that long-run employment is determined by demographic, policy and sociological factors that are independent of removal of global goods market distortions. For that reason, we adopt the conventional long-run labour market closure of exogenous aggregate national employment and allow the national real wage to be determined endogenously. As Dixon and Rimmer (2002, p. 76) argue, this is consistent with long-run exogeneity of the natural rate of unemployment, a familiar macro-economic modelling assumption. The nation's population also is treated as exogenous.

Since our focus is long-run, we allow labour to move between regions in response to regional wage differentials. However, we recognise that household locational preferences constrain labour movements even in the long-run. We model this by allowing regional employment to be endogenous, but sticky. Stickiness in regional labour supply is achieved by allowing the gap between the regional wage and the national wage to be weakly positively related to the movement in regional employment. In terms of our model results, this closure has the effect of ensuring that long-run regional labour market pressures mostly manifest as movements in regional employment, with only limited movement in relative regional wage rates.

We assume that the desired rate of capital accumulation in each regional industry in the long-run solution year is independent of the policy shock.[2] We implement this via exogenous determination of regional industry investment/capital ratios. With movements in long-run regional industry capital stocks largely determined by the first closure assumption above, this effectively links long-run movements in regional industry investment to movements in regional industry capital stocks. National investment is determined as the sum of regional industry investments.

[2] This is consistent with long-run exogeneity of rates of regional industry-specific productivity growth, labour/capital bias in technical change, and economy-wide employment growth.

We assume that removal of global trade distortions will have no effect on Australian preferences for current versus future consumption in the long-run solution year. That is, we assume that the rate of national savings out of national income will be unaffected by the policy shock. This is implemented by assuming that national (public plus private) consumption is a fixed proportion of gross national disposable income. Subject to this national constraint, we assume regional private consumption is a fixed proportion of regional income.

We assume that long-run regional public consumption spending will follow movements in the long-run regional distribution of economic activity. Regions in which long-run population, employment and consumption are rising (falling) receive a rising (falling) share of national public consumption spending. We model this via exogenous determination of region-specific ratios of real public consumption spending to real private consumption spending.

3. Results

3.1. Effects of distortions on incomes of Australian farmers and rural areas

To understand the impacts through the terms of trade effects on Australia of the rest of the world's farm and trade policies, we begin with the macroeconomic effects before turning to the sectoral and regional results. The macro impacts are decomposed into two effects: those attributable to changes in the prices for Australian exports (column 1 of Table 2) and those attributable to

Table 2 Macroeconomic effects in Australia of liberalizing rest of world's trade policies (per cent)

	Due to changes in		
	Export prices	Import prices	Total change
Real GDP at market prices	0.19	−0.03	0.15
Aggregate employment	0.00	0.00	0.00
Aggregate capital stock	0.32	−0.06	0.27
Real consumption (private & public)	0.63	−0.14	0.49
Real investment	0.64	−0.09	0.54
Real exports	−0.67	−0.11	−0.77
Real imports	1.60	−0.56	1.04
Terms of trade	2.30	−0.53	1.77
Real exchange rate	2.54	−0.16	2.37
Nominal exchange rate (foreign currency/$AUD)	2.08	−0.02	2.06
Consumption deflator (private & public)	0.01	−0.03	−0.02
Investment price deflator	−0.29	−0.01	−0.30
Rental price of capital	−0.45	0.00	−0.45
Rental price of land	23.7	0.56	24.3

Source: Authors' calculations using the TERM Model.

changes in the prices Australia pays for its imports (column 2). Column 3 reports the sum of those two effects.

Removal of distortions in global goods markets has a favourable effect on Australia's terms of trade: they improve by 1.8 per cent, made up of a 2.3 per cent improvement in export prices and offset by a 0.5 per cent change in import prices (Table 2, row 8). The increasing demand for agricultural exports lifts rental rates on agricultural land, by almost one-quarter (24 per cent, row 14). Together with the increase in the terms of trade, this encourages expansion of the long-run national capital stock (row 3). With the capital stock higher, so too is real GDP (row 1). The positive movements in real GDP and the terms of trade account for the 0.5 per cent increase in real consumption (row 4). Approximately 0.35 per cent age points of the total outcome for real consumption is attributable to the positive terms of trade outcome, with the remaining 0.15 percentage points due to the increase in real GDP. The strong positive movement in the terms of trade allows the real GNE outcome to exceed the real GDP outcome. This accounts for the movement towards deficit in the real balance of trade, which is expressed as a contraction in the aggregate volume of exports and an expansion in aggregate import volume (rows 6 and 7, column 3). The mechanism that achieves this is real appreciation, amounting to 2.4 per cent (row 9 of Table 2).

The real appreciation of the exchange rate means tradable sectors whose prices do not rise much could be under pressure to contract. Figure 1 shows that this is indeed what happens: virtually all agricultural and food industries

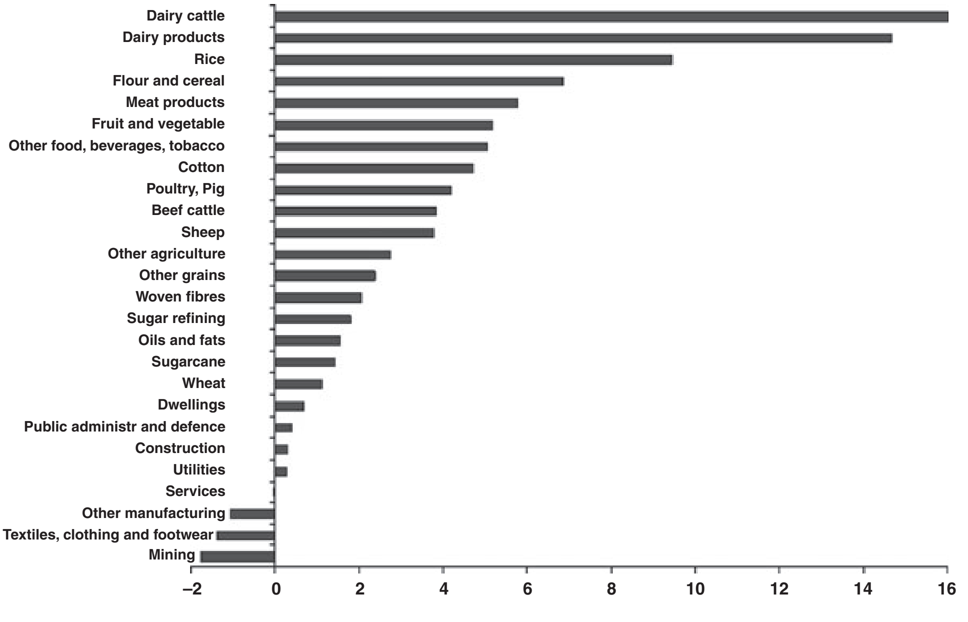

Figure 1 Effects on sectoral output volumes in Australia of liberalizing rest of world's trade policies. Source: Authors' TERM Model results (Percent).

expand (with dairying and rice benefiting most), but other manufacturing output shrinks by more than 1 per cent, and mining output shrinks by almost 2 per cent.

The TERM model has only one household, so it is not possible to say much about the effect on incomes of different groups within Australia. But a crude way of identifying how farmers are affected is to look at the change in agricultural GDP deflated by the consumer price index. The bias towards agriculture in the improvement in Australia's terms of trade ensures that agriculture's CPI-deflated value-added increases by 17.5 per cent, while non-agricultural CPI-deflated value added falls by 0.1 per cent (within which food processing rises by 6.5 per cent, mining and other manufacturing fall by 2.3 and 0.9 per cent, respectively, and services rise by 0.1 per cent).

The regional consequences of these sectoral changes can be seen in Figure 2. Our modelling assumes all regions within Australia experience the same commodity-specific percentage changes in export and import prices from removal of world agricultural and other trade distortions. As a result, regional differences in the industrial composition of local economic activity determine much of the dispersion in regional economic impacts. That is, regional income effects are strongly positive for rural regions, slightly negative for mining-intensive regions (the less-agricultural regions of Western Australia and South Australia, the Northern Territory, and Mackay and Fitzroy in Queensland), and mixed for urban regions (Figure 2). The rural results somewhat correlate with the regions most adversely affected by drought recently (see Horridge *et al.* 2005) and by Dutch-disease effects

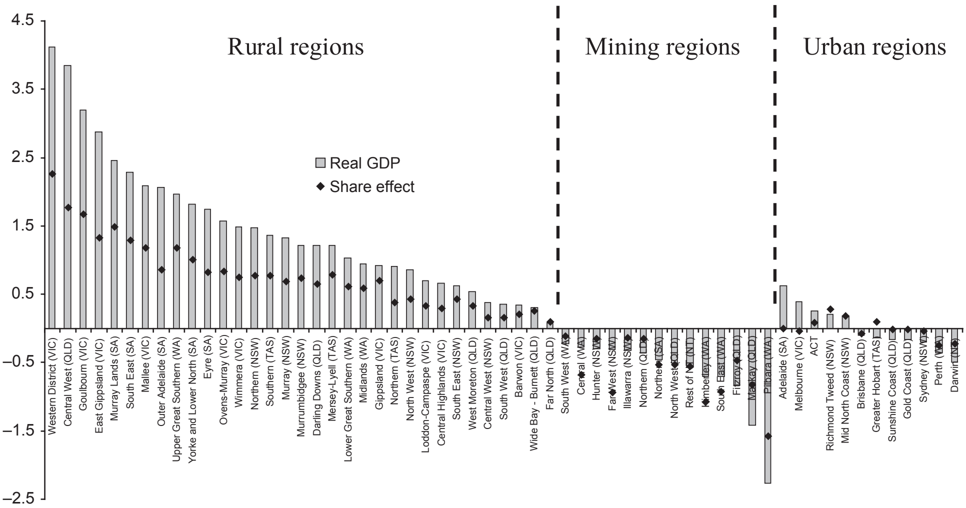

Figure 2 Real regional GDP impacts of rest of world trade liberalization and regional share effects[a]. [a]The 'share effect' shows how much of the real regional GDP result is due to fast-(slow-)growing industries being over- (under-)represented in a region (the residual being due to regional industries experiencing rates of growth that differ from the national average). Source: Authors' TERM Model results.

flowing from the mining boom (Horridge and Wittwer 2008), which means cuts to distortions in global goods markets could help offset such economic outcomes across Australian regions.

The urban results depend among other things on the extent to which an urban centre is specialized in servicing more the agricultural and food sector (as in Adelaide and Melbourne) rather than the mining sector (as in Perth and Darwin, which is where many miners live when they are not working on remote mine sites).

It is clear from Figure 2 that the income gains to rural areas are by no means uniform. Indeed, there is a wide variation, ranging from less than 0.1 per cent in Far North Queensland (where mining also occurs – see Appendix Table A1) to more than 4 per cent in the agriculturally lush Western Districts of Victoria. Again this reflects the regional differences in the industrial composition of local economic activity, given the wide range of output changes shown in Figure 2.

To look more deeply into such regional results, Adams *et al*. (2000) decompose the differences between regional and national GDP outcomes into individual contributions attributable to regional industry output movements. Specifically, they demonstrate that an industry makes a positive contribution to a region's relative growth rate if (i) it is a fast (slow-)growing industry, and it is over- (under-)represented in the region, and (ii) it grows more in the region than it does in the nation as a whole. They call the first of these the *share effect* and the second the *activity effect*.

As outlined in our earlier discussion of simulation design, in applying the LINKAGE model results to the bottom-up regional model TERM, we had no basis for assuming otherwise than that the sizes of commodity-specific movements in import prices and export demand schedules across regions are identical. Hence, for example, every region experiences a 9.9 per cent increase in foreign willingness to pay for sheep exports (row 1 of Appendix Table A2). While TERM is a bottom-up regional model, since we do not allow for commodity-specific export and import price shocks to differ across regions, we might expect that the 'share effect' will play an important role in explaining differences in regional GDP outcomes. This is shown in Figure 2 to be the case here, as the distribution of regional GDP outcomes is largely due to the share effect (its contribution being indicated by the star in each region's vertical bar). In Figure 2, we also see that regions with large positive share effects tend to experience large positive activity effects.[3] This reflects the stimulus to local firms producing intermediate inputs and consumption goods that is provided by a region possessing an above-average concentration of industries that do well from global trade reform.

[3] In Figure 2, the activity effect is the difference between the share effect, and regional real GDP less the national GDP outcome.

3.2. The bottom line

The key net effects of the changes reported above are that real net rural incomes in Australia would be 1.2 per cent higher, and real returns to agricultural land in particular would be 24 per cent higher, in the absence of price distortions resulting from agricultural and trade policies in the rest of the world.[4] Clearly those policies abroad are hurting Australia's rural households, adding to the adverse impact of drought over recent years (Horridge *et al*. 2005; Horridge and Wittwer 2008), but to varying extents depending on the product specialization of various regions and households. The upturn in international food prices in 2007–2008 brought a welcomed reprieve, which Australian farmers and trade negotiators hoped would help revive the agricultural part of the multilateral trade negotiations under WTO's Doha Development Agenda. The above results vindicate the continuing push by Australia's rural communities for multilateral agricultural trade liberalization and give additional reason for doing so to those regions most adversely affected by policies abroad.

We have not been able to provide estimates of the impact of those distortionary policies on household income distribution within and between regions in Australia, and in particular on the change in the number of people in poverty in each region. This is clearly an area for further research. Methodologies and computational capabilities for doing that have advanced rapidly in recent years (see, for example, Bourguignon *et al*. 2008), and their application to select developing countries has begun (Hertel and Winters 2006; and Anderson *et al*. 2010a). To undertake this task for Australia will require the addition of a multi-household structure to our multi-regional model, ideally with full inter-regional and inter-household accounting of post-tax primary factor flows and transfer payments.

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[4] Even though incomes in mining regions would be 0.7 per cent lower on average, those regions currently enjoy incomes that are substantially higher than in the rest of Australia and so could well absorb that shock.

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Appendix

Derivation of export demand elasticities implicit in the LINKAGE model's parameters and theoretical structure

Economic agents within each country in the LINKAGE model face a two-stage sourcing decision problem. First, agents assemble a composite

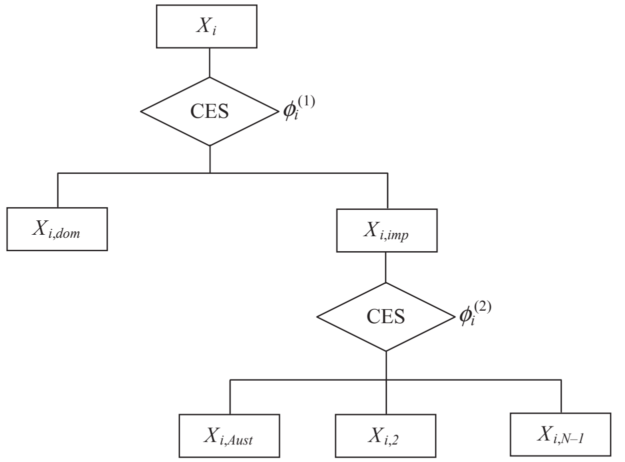

Figure A1 LINKAGE Model's commodity sourcing structure. Source: Authors' derivation based on van der Mensbrugghe (2005).

commodity *i* via a CES aggregation of domestic commodity *i* and a composite of imported commodity *i*. Second, the composite import is assembled from alternative foreign sources via a CES aggregation function.

Following the approach outlined in Dixon and Rimmer (2002, pp. 222–225), we derive the Australia-specific export demand elasticities implicit in LINKAGE as follows. On the assumption that only the price of the Australian good is varying, from the familiar form for the linearized cost-minimizing demand equations implicit in the economic problem represented in the bottom nest in Figure A1, we know that demand for the Australian good is given by:

$$x_{i,Aust} = x_{i,Imp} - \phi_i^{(2)}(p_{i,Aust} - S_{i,Aust}p_{i,Aust}) \tag{1}$$

or

$$x_{i,Aust} = x_{i,Imp} - \phi_i^{(2)}(1 - S_{i,Aust})p_{i,Aust} \tag{2}$$

where $S_{i,Aust}$ is Australia's share in world trade in *i*.
From the top nest, we know that demand for the imported good is given by:

$$x_{i,Imp} = x_i - \phi_i^{(1)}(p_{i,Imp} - p_i) \tag{3}$$

On the assumption that only the price of the Australian good is varying (3) simplifies to:

$$x_{i,Imp} = x_i - \phi_i^{(1)}(S_{i,Aust}p_{i,Aust} - S_{i,Imp}S_{i,Aust}p_{i,Aust}) \tag{4}$$

which simplifies to:

Table A1 Sectoral shares of gross regional product and regional shares of GDP and population, Australia, 2004

	Sectoral shares (%, relative to sectoral share of national GDP)			Share of national GDP (%)	Share of national population (%)
	Agriculture	Mining	Other sectors		
Rural				15.9	19.1
CentlWestQLD	14.92	0.1	0.56	0.1	0.1
UpperGtSthWA	14.14	0.1	0.58	0.1	0.1
MidlandsWA	13.60	0.3	0.52	0.4	0.3
EyreSA	10.96	0.2	0.73	0.2	0.2
YorkLwrNthSA	10.33	0.2	0.74	0.2	0.2
WimmeraVIC	9.80	0.4	0.72	0.3	0.4
SouthEastSA	8.78	0.3	0.79	0.3	0.3
WestnDistVIC	7.99	0.5	0.82	0.5	0.5
SouthWestQLD	7.80	0.1	0.39	0.3	0.1
SouthernTAS	7.36	0.2	0.86	0.1	0.2
MalleeVIC	6.97	0.3	0.87	0.4	0.3
DarlDownsQLD	6.41	1.1	0.81	1.1	1.1
NorthernNSW	6.25	0.9	0.89	0.8	0.9
MurrayLndsSA	6.20	0.3	0.90	0.3	0.3
LowerGtSthWA	5.49	0.3	0.87	0.3	0.3
NorthWestNSW	5.42	0.6	0.81	0.5	0.6
GoulbournVIC	4.87	0.8	0.95	0.9	0.8
EastGippsVIC	4.55	0.3	0.93	0.3	0.3
MurrayNSW	3.92	0.6	0.98	0.5	0.6
MrmbidgeeNSW	3.58	0.7	0.99	0.7	0.7
WideByBntQLD	3.51	1.3	0.89	0.9	1.3
OtrAdelaidSA	3.38	0.6	0.99	0.5	0.6
MerseyLylTAS	3.19	0.6	0.93	0.4	0.6
WMoretonQLD	3.11	0.4	0.88	0.3	0.4
CentrlWstNSW	2.98	0.9	0.87	0.9	0.9
NorthernTAS	2.79	0.7	1.01	0.5	0.7
OvensMrryVIC	2.33	0.5	1.04	0.4	0.5
GippslandVIC	2.19	0.8	0.95	1.0	0.8
FarNorthQLD	2.03	1.2	0.99	1.0	1.2
SouthEastNSW	1.76	1.0	1.06	0.9	1.0
CentHilndVIC	1.64	0.6	1.05	0.6	0.6
LoddonCmpVIC	1.54	1.0	1.04	0.7	1.0
BarwonVIC	1.34	1.3	1.07	1.2	1.3
Mining				13.1	9.0
PilbaraWA	0.06	11.1	0.15	1.7	0.2
KimberleyWA	1.83	8.69	0.30	0.4	0.2
FarWestNSW	0.97	7.39	0.44	0.2	0.1
SouthEastWA	1.46	6.90	0.47	0.5	0.3
NorthWestQLD	3.84	6.81	0.39	0.3	0.2
MackayQLD	1.17	6.65	0.50	1.4	0.8
CentralWA	3.39	6.24	0.46	0.5	0.3
NorthernSA	2.30	4.87	0.61	0.5	0.4
FitzroyQLD	2.06	4.29	0.67	1.6	1.0
RoNT	0.68	4.07	0.74	0.8	0.7
SouthWestWA	1.39	2.40	0.86	1.1	1.0
IllawarraNSW	0.14	2.0	1.05	1.8	2.0
NorthernQLD	1.13	1.88	0.92	1.0	1.0

Table A1 (*Continued*)

	Sectoral shares (%, relative to sectoral share of national GDP)			Share of national GDP (%)	Share of national population (%)
	Agriculture	Mining	Other sectors		
HunterNSW	0.36	1.51	0.98	3.1	3.0
Urban				71.0	72.0
SydneyNSW	0.05	20.7	1.12	22.0	20.7
ACT	0.02	1.6	1.12	2.0	1.6
AdelaideSA	0.21	5.5	1.11	4.6	5.5
GrtHobartTAS	0.48	1.0	1.10	0.7	1.0
MelbourneVIC	0.11	18.2	1.10	17.7	18.2
RichTweedNSW	0.80	1.1	1.09	1.8	1.1
MidNthCstNSW	0.76	1.4	1.09	0.8	1.4
GoldCoastQld	0.54	2.5	1.07	2.0	2.5
BrisbaneQLD	0.11	8.8	1.07	8.2	8.8
SunshnCstQld	0.72	1.4	1.04	1.1	1.4
PerthWA	0.21	7.3	0.97	7.8	7.3
DarwinNT	1.04	0.3	0.88	0.5	0.3
National average shares	3.2	7.8	89.0	100.0	100.0

Urban = Capital cities and other regions with relative share > 1.03 unless rural relative share is greater (viz. BarwonVIC, SouthEastNSW, CentHilndVIC, LoddonCmpVIC, OvensMrryVIC). Mining = regions with relative share > 1.5 unless rural relative share is greater (SouthWestQLD, CentrlWstNSW), or it is a capital city (viz. Perth, Darwin). Source: TERM model's database, drawn from Australian Bureau of Statistics data.

$$x_{i,Imp} = x_i - \phi_i^{(1)} S_{i,Aust} S_{i,Dom} p_{i,Aust} \tag{5}$$

Finally, we assume that demand for x_i is sensitive to its own price. We represent this with the following constant elasticity demand schedule

$$x_i = -\eta_i p_i \tag{6}$$

Assuming that only the price of the Australian good is varying, this simplifies to:

$$x_i = -\eta_i S_{i,Aust} S_{i,Imp} p_{i,Aust} \tag{7}$$

Substituting (7) and (4) into (2) yields.

$$x_{i,Aust} = -[\eta_i S_{i,Aust} S_{i,Imp} + \phi_i^{(1)} S_{i,Aust} S_{i,Dom} + \phi_i^{(2)} (1 - S_{i,Aust})] p_{i,Aust} \tag{8}$$

In equation (8), $p_{i,Aust}$ is the purchaser's price in the foreign country of Australian good i. Movements in this price can be divided into two parts: movements in the f.o.b price of Australian good i, and movements in transaction charges and taxes related to getting the good from Australia to the user in the foreign country. In the absence of changes in such charges and taxes, $p_{i,Aust}$ depends only on $p_{i,Aust}^{fob}$, the percentage change in the f.o.b price of Aus-

Table A2 Commodity-specific import price shocks, and estimates of export price impacts of rest of world trade liberalization on Australia, 2004

Australian TERM model sector	Vertical (willingness-to-pay) shifts in export demand	Changes in import prices
1. Sheep	9.93	10.59
2. Wheat	3.14	0.00
3. Other grains	5.02	2.58
4. Rice	8.33	0.00
5. Beef cattle	2.34	8.25
6. Dairy cattle	0.00	−1.31
7. Other livestock	1.74	1.03
8. Cotton	7.31	−1.30
9. Vegetables and fruit	5.03	2.32
10. Sugar cane	0.00	0.00
11. Other agriculture	4.28	0.94
12. Mining	0.75	4.01
13. Meat products manufacturing	11.18	5.90
14. Dairy products manufacturing	29.08	12.05
15. Fruit and vegetable manufacturing	11.43	3.41
16. Oils and fats manufacturing	4.85	0.98
17. Flour and cereal manufacturing	10.74	3.52
18. Other food, beverages, and tobacco manufacturing	11.43	3.41
19. Sugar refining	3.66	1.10
20. Woven fibres	7.14	9.95
21. Textiles, clothing and footwear	3.45	−0.34
22. Other manufacturing	1.10	0.09
23. Utilities	−1.37	−0.27
24. Construction	−1.37	−0.27
25. Dwellings	−1.37	−0.27
26. Public administration and defence	−1.37	−0.27
27. Services	−1.37	−0.27

Source: Derived by the authors from Linkage model results reported above in Table 1 (from van der Mensbrugghe *et al*. 2010).

tralian good i, and $S^{fob}_{i,Aust}$, the share of the f.o.b price in the foreign country purchaser's price:

$$p_{i,Aust} = S^{fob}_{i,Aust} p^{fob}_{i,Aust} \tag{9}$$

Substituting (9) into (8) we have:

$$x_{i,Aust} = -[\eta_i S_{i,Aust} S_{i,Imp} + \phi^{(1)}_i S_{i,Aust} S_{i,Dom} + \phi^{(2)}_i (1 - S_{i,Aust})] S^{fob}_{i,Aust} p^{fob}_{i,Aust} \tag{10}$$

Hence, the Australian export demand elasticity for good *i* implicit in the LINKAGE theory and database is

$$\eta^{(Linkage)}_t = -[\eta_i S_{i,Aust} S_{i,Imp} + \phi^{(1)}_i S_{i,Aust} S_{i,Dom} + \phi^{(2)}_i (1 - S_{i,Aust})] S^{fob}_{i,Aust}$$

and so its value can be determined from the LINKAGE values of:

η_i The elasticity of demand for good i (irrespective of source) in the foreign country. Typically, we might expect the value for η_i to be low, perhaps around 0.10.

$S_{i,Aust}$ Australia's share in world trade for good *i*. For wool, the value for $S_{i,Aust}$ is quite high (around 0.65). For most commodities, it is quite low (around 0.05).

$S_{i,Imp}$ The import share in world usage of commodity *i*. A typical value for $S_{i,Imp}$ is around 0.15.

$S_{i,Dom}$ The domestic sourcing share in world usage of commodity *i* $(= 1 - S_{i,Imp})$. A typical value for $S_{i,Dom}$ is around 0.85.

$\phi_i^{(1)}$ The elasticity of substitution between domestic and imported varieties of good i. In LINKAGE, a typical value for $\phi_i^{(1)}$ is around 4.

$\phi_i^{(2)}$ The elasticity of substitution between alternative foreign sources of supply for imported good i. In LINKAGE, a typical value for $\phi_i^{(2)}$ is around 8.

$S_{i,Aust}^{fob}$ The share of the f.o.b price in the foreign country purchaser's price of good i. A typical value for $S_{i,Aust}^{fob}$ is 0.7.

Hence, in LINKAGE, a typical value for the Australian export demand elasticity for commodity *t* is:

$$\eta_t^{(Linkage)} = -[0.10 \times 0.05 \times 0.15 + 4 \times 0.05 \times 0.85 + 8 \times (1 - 0.05)] \times 0.7 = -7.7.$$