PART III

APPLICATIONS OF GTAP

CHAPTER 7

Developing country expansion and relative wages in industrial countries

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I Introduction and overview

Changes in the labor markets of the developed countries since the 1970s have been the subject of extensive empirical analysis (Murphy and Welch 1989; Freeman 1993; Gregory and Vella 1993; Katz, Loveman, and Blanchflower 1993; Freeman and Katz, 1994). The principal stylized facts to emerge from this analysis are that (1) real wage inequality has increased in most Organization for Economic Cooperation and Development (OECD) member countries (the few exceptions including Japan), (2) this trend has been strongest in the US in the 1980s and weaker in those countries where wage determination is more centralized, and (3) the rate of unemployment has risen more where the trend toward wage dispersion has been weakest. Numerous explanations have been advanced for the trend in the US. Those that emphasize labor supply include that growth in the supply of skilled workers slowed in the 1980s (Katz, Loveman, and Blanchflower 1993) and that immigration of unskilled workers has accelerated (Borjas, Freeman, and Katz 1991). Those emphasizing labor demand argue that technological change has been unskilled labor–saving (Mincer 1991; Bound and Johnson 1992) and that an expansion in imports that are intensive in unskilled labor has shifted the product composition of domestic output in ways that foster growth in the demand for skilled rather than unskilled labor (Murphy and Welch 1991; Wood 1991a,b 1994; Leamer 1993).

It is the last of these explanations that we explore further. We find the labor demand approach more attractive than the labor supply explanations because the latter are country-specific and the trend toward more wage dispersion seems general. Although we accept that labor saving technical change has played a role, it is possible that fine shifts in the mix of products in a given industry, which are induced by competition with imports, may show up in empirical analysis as changes of technology. Bound and Johnson (1992), for example, use only 17 industry groups, of which the manufacturing sector is a part of only two. The remainder are mainly nontraded service industry categories. Clearly, it has been the manufacturing sector in the developed countries that has endured enhanced competition from labor-intensive imports while at the same time expanding its exports of skill-intensive products. The documented decline in employment in that sector, combined with an apparent increase in its average wage in the US, is consistent with the possibility that both the level of employment and the average wage of unskilled workers in manufacturing there has fallen substantially.

Recent analysis at the two-digit International Standard Industrial Classification (ISIC) level by Lawrence and Slaughter (1993) [also drawn upon extensively by Krugman and Lawrence (1993)] finds that employment has become more skill-intensive in all sectors, despite a decline in the relative cost of unskilled labor. To them, this suggests that domestic technology changes dominate trade effects in causing increased wage dispersion. While this may indeed be true, their paper concedes that changes in trade composition may also have contributed, and no empirical apportionment is attempted. Moreover, the studies to date have emphasized the analysis of the domestic product and labor markets and not the international setting in which the pattern of trade flows is determined. Yet, the latter is required if one is to understand the factors that have induced the rise in labor-intensive imports and, presumably, the corresponding rise in exports by developed countries of products intensive in other factors.

Since the 1970s, a growing number of developing countries have changed their trade policy regimes in favor of "outward orientation" (Whalley 1989). This "opening up" has been associated with substantial growth in exports by developing countries and with a shift in the composition of those exports away from products intensive in natural resources toward labor intensive manufactures (IMF 1993, chap. VI). There is, of course, little doubt that these developments have fostered growth in the global economy and that factors other than unskilled labor have been beneficiaries in the developed countries. Indeed, the improvements in productivity and factor use associated with developing country growth are very likely Pareto-improving *across* countries (Kemp, Ng, and Shimomura 1993). Our concern is to explore the effect of these developments on inequality *within* the developed countries.

In part, this concern has its origins in two basic theorems of the traditional two-factor, two-sector Heckscher–Ohlin–Samuelson (HOS) trade model: the factor price equalization (FPE) and Stolper–Samuelson (SS) theorems. The FPE theorem provides conditions under which free trade, which is assumed to equalize product prices across countries, also equalizes factor rewards. The SS theorem relates changes in product prices to factor rewards. An increase in the price of the relatively labor intensive product increases the real return to labor and reduces the real return to capital. This implies that if developed countries have used trade interventions to protect relatively labor-intensive import competing sectors and developing countries have similarly protected their relatively capital-intensive import competing sectors, then protection would be at least partly responsible for real wages being higher in the developed countries. As trade restrictions are scaled down by both groups of trading partners, this would suggest a convergence of factor rewards in both and a decline in the real return to pure labor in developed countries. Hereafter, we refer to this as the HOS result.

There are, however, a number of reasons why the HOS result might not be observed. To start with, some results from the HOS model either disappear or need reinterpretation once its more restrictive assumptions are relaxed. In particular, extensions to more than two products, factors, or countries; unequal numbers of products and factors; and the allowance of some specialization in production all reduce the sharpness with which the conclusion may be drawn that trade reform leads to factor price convergence (Ethier 1984; Deardorf 1986; Falvey 1991). But the potential for extensions does not end there. A more accurate model would allow for the following:

1. The existence of nontraded goods and services, many of which are intensive in unskilled labor
2. The differentiation of products at the level of the firm or the country of origin
3. The comparative international mobility of some forms of capital
4. Consumption behavior driven by nonhomothetic preferences, such that rich households whose income is derived principally from capital have higher propensities to consume labor-intensive goods and services.

These extensions of the basic model enhance the role of income effects of trade reforms in ways that run counter to substitution effects in demand. As trade reforms raise incomes in both the developing and developed countries, the shifting of demand in the developed countries from home products to imports is less complete. Indeed, nontraded and some traded labor-intensive home product and service industries would actually face rising demand. The international mobility of capital ensures that remaining distortions and product differentiation do not retard the growth of capital income in the developed countries. And nonhomothetic preferences allow the wealthier households to spend this new income more than proportionately on labor-intensive home products and services. Moreover, the poorer households in the developed countries would then have consumption bundles that are more intensive in the imported products of the developing countries. Other things equal, trade reform should raise the purchasing power of those households.

In this chapter we explore the consequences of some of these extensions to the basic model of trading economies. For this we use the global data base assembled originally for the SALTER Project (Jomini et al. 1991) and updated and modified for the Global Trade Analysis Project (GTAP) (see Chapter 3) The analysis to be presented also uses the GTAP modeling framework as laid out in Chapter 2 of this book.[1] For consistency with other work presented in this volume, we do not go so far as to examine nonhomotheticity of preferences by disaggregating among rich and poor households.[2] Moreover, our analysis is constrained by the model's consolidation of both skilled and unskilled labor into a single factor. It is therefore impossible to separate derived demands for pure labor and human capital. Both this, and the model's differentiation of products by country of origin, render the pure HOS result unlikely. Nonetheless, labor as a broad group in the older industrial economies (OIEs) emerges as losing, relative to capital and land, from reforms and subsequent rapid growth in the rapidly developing Asian economies (RDEs). However, it gains relative to final product prices.

II Aggregation strategy

The GTAP data base divides the world into 24 countries and has 37 commodities and 3 primary factors (labor, capital, and agricultural land). For our purpose it is aggregated to 6 regions and 10 commodity groups, as indicated in Table 7.1. This regional aggregation best highlights the contrasts between the OIEs and the RDEs whose impacts on the former we wish to estimate. The commodity aggregation is based on an analysis of the factor proportions adopted in each industry in the OIEs. The 10 commodity groups are chosen so as to maximize *between*-group differences and minimize *within*-group differences in the split of factor payments between labor and the other factors. This is done for the average of the three OIEs: North America, the European Union (EU), and Australasia.

In any examination of factor market impacts of economic reform, the results depend crucially on the extent of the between-group differences in factor intensities. Shares of direct and total (direct and indirect) expenditure on the three primary factors, as derived from the 1992 data base, are listed in Table 7.2. (Aggregated trade elasticities are reported in Table 7.3.[3]) The two groups of capital-intensive manufactures have only slightly different total factor requirements, when indirect factor demands are added. The "highly capital-intensive" group is consistently more capital-intensive so long as capital is defined broadly to include land. Petroleum and coal products are also relatively capital-intensive.

The labor-intensive manufacturing groups have compositions that are nontraditional. The light manufactures mainly exported by developing countries

Table 7.1. *Regional and Commodity Aggregation*

Regional Aggregation	Commodity Aggregation
1. Australasia	**1. Crops**
Australia	Paddy rice
New Zealand	Wheat
	Grains
2. North America	Nongrain crops
Canada	
US	**2. Other agriculture, forestry, and fishing**
	Wool
3. EU	Other livestock
The former European Community of 12	Forestry
	Fisheries
4. Rapidly developing	
China	**3. Mining**
Indonesia	Coal
Hong Kong	Petroleum
Malaysia	Gas
Singapore	Other minerals
Republic of Korea	
Taiwan	**4. Highly capital-intensive manufacturing**
Thailand	Processed rice
	Meat products
5. Japan	Milk products
	Other food products
6. Slowly developing	
Argentina	**5. Moderately capital-intensive manufacturing**
Brazil	
Mexico	Beverages and tobacco
Rest of Latin America	Chemicals, rubbers, and plastics
sub-Saharan Africa	Other manufacturing
Middle East	
North Africa	**6. Moderately labor-intensive manufacturing**
	Textiles
	Leather goods
	Lumber and wood products
	Pulp and paper
	Nonmetallic minerals
	Fabricated metal products
	7. Highly labor-intensive manufacturing
	Wearing apparel
	Primary ferrous metals
	Transport industries
	Machinery and equipment
	8. Petroleum and coal products
	9. Labor-intensive services
	Electricity, water, and gas
	Construction
	Trade and transport
	Other private services
	Other government services
	10. Capital-intensive services
	Ownership of dwellings

are not concentrated in the "highly labor-intensive" group but are distributed across the four manufacturing groups. This stems in part from the consolidation of skilled with unskilled labor in the data base, since the skill level and the average wage of most workers in light manufacturing might be expected to be lower than in heavy manufacturing.[4] It also stems from the use of factor proportions in the OIEs in designing the industry aggregation. According to Wood (1994), light manufactures imported from developing countries have more labor content than the home goods with which they now compete in the

Table 7.2. *Factor Proportions by Industry in the OIEs*

	Share of (Direct[a]) and Total[b] Industry Expenditure on Domestic Factors								
	North America			European Union			Australia		
	Labor	Capital	Land	Labor	Capital	Land	Labor	Capital	Land
Crops	(38)[a] 49	(42) 40	(20) 11	(68) 67	(21) 26	(11) 7	(55) 56	(16) 19	(29) 25
Other agriculture, forestry and fishing	(44) 52	(46) 41	(10) 7	(61) 63	(30) 31	(9) 6	(48) 52	(25) 28	(27) 20
Mining	(25) 36	(75) 64	(0) 0	(69) 67	(31) 33	(0) 0	(26) 37	(74) 63	(0) 0
Highly capital-intensive manufacturing	(52) 54	(48) 42	(0) 3	(57) 62	(43) 34	(0) 3	(61) 59	(39) 32	(0) 9
Moderately capital-intensive manufacturing	(54) 56	(46) 44	(0) 0	(69) 67	(31) 32	(0) 0	(54) 59	(46) 40	(0) 1
Moderately labor-intensive manufacturing	(70) 67	(30) 33	(0) 0	(73) 71	(27) 29	(0) 0	(63) 62	(37) 36	(0) 1
Highly labor-intensive manufacturing	(79) 73	(21) 27	(0) 0	(80) 76	(20) 24	(0) 0	(75) 69	(25) 30	(0) 0
Petroleum and coal products	(62) 56	(38) 44	(0) 0	(11) 22	(89) 78	(0) 0	(40) 54	(60) 45	(0) 0
Labor-intensive services	(65) 65	(35) 35	(0) 0	(73) 72	(27) 28	(0) 0	(69) 68	(31) 32	(0) 0

[a] Shares of factors employed directly in each industry to total value-added are reported in parentheses. Note that the excluded final category, ownership of dwellings, employed only capital.
[b] Includes indirect factor requirements, i.e., factor content of intermediate inputs into the industry. Total requirements coefficients were normalized to exclude indirect taxes and imports.
Source: GTAP model data base version 2. (See Chapter 3.)

Table 7.3. *Aggregate Elasticities of Substitution in Demand*[a]

	Between Home Goods and Generic Imports	Between Imports According to Source
Crops	2.2	4.4
Other agriculture, forestry, and fishing	2.8	5.5
Mining	2.8	5.6
Highly capital-intensive manufacturing	2.2	4.4
Moderately capital-intensive manufacturing	2.2	4.4
Moderately labor-intensive manufacturing	2.5	5.4
Highly labor-intensive manufacturing	3.5	7.0
Petroleum and coal products	1.9	3.8
Labor-intensive services	1.9	3.9

[a] Note that the final category, ownership of dwellings, is not traded and therefore is excluded from above.

Table 7.4. *The Regional Share of World Population and GDP in 1970(%)*[a]

	Population	GDP
Australasia	.5	1.7
North America	6.9	41.5
EU	9.7	26.2
Rapidly developing	31.3	5.1
Japan	3.2	7.7
Slowly developing	48.4	17.8
Total	100.0	100.0

[a] Shares of global nominal gross domestic product (GDP), calculated by adding nominal regional GDP values, converted to $US using current exchange rates.
Source: World Bank, *World Tables* data base.

OIEs. This militates further against the model exhibiting strong HOS effects from developing country trade reform. Although a simulated surge of developing country imports might accurately predict the resulting change in home industry outputs, it is likely to yield an underestimate of the resulting change in the home sector's labor intensity.

III Growth and economic openness: The stylized facts

The contrast between the performance of economies that were poor in 1970 but have performed well since and those that were then already industrialized is best drawn between the OIEs of North America, Western Europe and Australasia, and the RDEs, which include Mainland China, Taiwan and Hong Kong, the Association of South East Asian Nations (ASEAN), and the Republic of Korea. It is evident from Table 7.4 that the rapidly developing group had about a third of the world's population in 1970 and about a twentieth of its recorded output.[5]

Table 7.5. *Economic Openness: Interregional Exports as Shares of GDP, (%)*[a]

	1970	1990	Change, % GDP
Australasia	12.6	13.1	0.6
North America	3.7	5.7	1.9
EU	7.9	9.0	1.0
Rapidly developing	6.8	25.8	19.0
Japan	9.5	9.8	0.3
Slowly developing	14.7	17.8	3.1

[a] Exports exclude intraregional trade.
Source: GDP estimates are from the World Bank, *World Tables* data base. Exports are from the United Nations International Trade Statistics, as supplied by the Australian National University's International Economic Databank.

Table 7.6. Measures of Growth, 1970—1990, (%)[a]

	Labor Use	Capital Stock	Total Factor Productivity	Real GDP
Australasia	33	114	19	77
North America	22	82	30	76
EU	7	101	42	69
Rapidly developing	41	554	75	334
Japan	18	320	61	134

[a] Because their sources are disparate, there is no necessary consistency between the four columns of this table and any particular GDP function. Complete statistics on all columns are unavailable for the slow-growing developing group of economies.
Source: Labor use growth is based on population statistics from the World Bank, *World Tables* data base. The use of population here implies the assumption that age distributions and participation rates remained constant. Capital use and total factor productivity growth estimates are from Nehru and Dhareshwar (1993). Real GDP changes are from a revised version of the *Penn World Tables*, described originally by Summers and Heston (1991).

The RDEs were typical of many developing countries until the early 1970s in that their international commerce was retarded by a combination of high infrastructure costs, poor communications, and, most important, substantial tariff and nontariff barriers to trade. Beginning at various times after 1970 they, and numerous other developing countries, began to pursue export-led growth (World Bank 1993). Barriers to trade were reduced and international commerce actively fostered. A consequence of this, as indicated in Table 7.5, was a surge in exports and a considerable increase in economic openness during the subsequent two decades. By 1990, the RDEs were by far the most open of the regions identified.[6]

Associated with this increase in economic openness in many developing countries was comparatively strong growth performance. This is evident from Table 7.6, in which the contributions to overall growth of increased primary factor use and total factor productivity are separated out. From the last column it is clear that, of the regions identified in the model, the RDEs are aptly named. Their growth was facilitated primarily by a substantial increase in the capital stock, although rapid population growth also contributed. There is also evidence that comparatively large gains were made in these countries in total factor productivity (Nehru and Dhareshwar 1993). The sectoral impact of their

Table 7.7. *Trade Between the RDEs and the OIEs*[a] *(1992 $US billion)*

	From Rapidly Developing to Industrial	From Industrial to Rapidly Developing
Crops	5	7
Other agriculture, forestry, and fishing	3	4
Mining	4	6
Highly capital-intensive manufacturing	5	5
Moderately capital-intensive manufacturing	35	27
Moderately labor-intensive manufacturing	41	19
Highly labor-intensive manufacturing	114	81
Petroleum and coal products	1	2
Labor-intensive services	31	23
Ownership of dwellings	0	0
Total	238	174

[a] The OIEs include Australasia, North America, and the EU.
Source: The GTAP data base version 2. (See also Chapter 3.)

expansion, combined with increased openness, is indicated by the composition of their trade with the OIEs in 1990, shown in Table 7.7. Half the value of their exports is in the highly labor-intensive group of products. However, the industry aggregation chosen tends to mask the contrast between the composition of their exports to the OIEs and their imports from them. Their imports include a smaller proportion of "moderately labor-intensive" products than their exports, but the substantial share in their imports due to labor-intensive products clearly includes heavy manufactures, which are intensive in human capital rather than raw labor.[7]

IV Experimental design

The effects on the OIEs of the trade, and other reforms that brought about the increased openness in the RDEs, are readily examined using the GTAP model. Since it is comparative static, however, the GTAP model cannot represent all the mechanisms that link those reforms to growth. The analysis therefore focuses, first, on the pure comparative static effects of the trade reforms necessary to achieve the observed increase in openness and, second, on the associated growth, introduced as exogenous changes in regional primary factor use. For this, the three scenarios delineated in Table 7.8 are sufficient.

In the first scenario, we ask how the world would have looked in the early 1990s, had the RDEs not shown extraordinary openness and growth performance over the two decades since 1970. They are assumed to have

Table 7.8. *Scenarios for the RDEs, 1970—1990*[a]

	Growth, 1970—1990, %			1990 Openness[a]
	Labor Use	Capital Use	Total Factor Productivity	$\frac{X}{(GDP-X+M)}$ Percent
Scenarios for 1990:				
Scenario 1: Reference Remain closed and grow like OIEs[b]	14	92	0	7
Scenario 2: Open Open but still grow like OIEs	14	92	0	26
Scenario 3: Open with growth Open and grow rapidly	41	554	0	26

[a] The ratio of exports to absorption. This is used because these are the two components of total supply (C + I + G + X) and their ratio is comparable across regions. In scenario 1 this is assumed to expand between 1970 and 1990 in the same proportion as (and hence not faster than) the older industrial countries.
[b] The OIEs are Australasia, North America and the EU.
Source: Derived from observations presented in Tables 7.5 and 7.6.

opened more gradually and grown more slowly (at the precise average rate of the OIEs). This provides a reference against which it is possible to compare the remaining two scenarios. Scenario 2 introduces the economic reforms necessary to bring the levels of openness of these economies up to their observed values in the current GTAP data base.[8] Factor use in this scenario is as for the first. It is important to note that the closure chosen for all scenarios fixes factor use and renders unit factor rewards endogenous. Unlike the first two scenarios, the third requires no model simulation. It is that in which the policy reforms are undertaken and the comparatively rapid growth ensues in the RDEs, leading ultimately to the world characterized in the current data base.

Note that the scenarios are not different as to total factor productivity (TFP). The results on TFP to which we have access [such as those from Nehru and Dhareshwar (1993)] are at the economywide level only. Substantial single-country evidence suggests that productivity gains have been unevenly distributed across industries and that, in developing countries, they have been associated with exports (World Bank 1993, chap. 6). In the absence of an industry-specific data base on TFP we chose to construct scenarios 1 and 2 based on factor use and openness alone. The scenario 1 gain in GDP in the RDEs turned out to be precisely that anticipated from the final column of Table 7.6.[9] Pending further information on the industry distribution of changes in technology, no complementary technology shocks have been applied.[10]

V Simulated effects of openness and growth

Comparing scenarios 2 and 3 with 1, the effects of openness and growth on the quantities produced in the OIEs are given in Table 7.9. There are two consistent effects. First, agriculture expands in the OIEs. This is a clear HOS

Table 7.9. ***Changes in Sectoral Output in the OIEs***[a]

	Percent Change in the Volume of Output					
	North America		European Union		Australasia	
	Open	Open With Growth	Open	Open With Growth	Open	Open With Growth
Crops	.9	4.9	-.7	1.8	.8	6.8
Other agriculture, forestry, and fishing	.3	1.3	-.1	.4	.9	3.4
Mining	.5	-.3	-.3	-.6	3.6	-3.3
Highly capital-intensive manufacturing	.1	.4	-.1	.2	-.4	1.1
Moderately capital-intensive manufacturing	-.6	-.7	-.7	-.7	-2.7	-3.6
Moderately labor-intensive manufacturing	-1.2	-1.9	-.7	-1.1	-1.9	-2.2
Highly labor-intensive manufacturing	-.8	-1.3	-1.2	-1.4	-4.2	-5.6
Petroleum and coal products	.1	.2	.0	.0	.7	.6
Labor-intensive services	.2	.2	.3	.3	.1	.2
Ownership of dwellings	.2	.3	.2	.2	.7	1.3

[a] Listed are proportional departures of scenarios 2 and 3 from the reference scenario (Table 9.8).
Source: Simulations of the GTAP model, as discussed in the text.

result, since the RDEs comprise predominantly land-scarce, densely populated countries. Their expansion raises the excess demand for the land-intensive agricultural exports of the OIEs. Second, all but the most capital-intensive of the manufacturing industry groups decline. This is another HOS result, since the OIEs have a comparative disadvantage in labor-intensive manufacturing relative to the RDEs. Both emerge as purely comparative static effects of the policy reform (openness only) and are enhanced by the associated growth reflected in scenario 3.

The particularly large amplification of the expansion of OIE agriculture when RDE growth is added is a further HOS effect, consistent with the Rybczynski Theorem. The principal source of RDE growth is an increase in the region's capital stock. Terms-of-trade changes are not large, since the RDEs still supply only 6% of global GDP.[11] The tradeable goods sector most intensive in capital – namely, manufacturing – expands while other tradeable goods sectors, including agriculture, contract. There is another reason for this enhancement that helps to explain why the crops sector of the EU contracts under the pure comparative statics of the trade reform (openness only). It is not due to any HOS effect but, instead, to the differentiation of home products from imports. The EU contraction results from a decrease in domestic absorption of agricultural products. This occurs because of a contraction in capital-intensive manufacturing (particularly food processing), which is a major user of agricultural products. The combination of openness with growth, however, raises export demand in the EU sufficiently to compensate for the decline in domestic absorption.

A final point to emerge from Table 7.9 is that the OIE structural change that stems from RDE openness and growth is most extensive in Australasia. This is because the intensity of Australasia's trade with the populous Asian economies is greater than that for either North America or the EU.

The corresponding aggregate effects on welfare, GDP, and exports are given in Table 7.10. OIE welfare, measured as an index of the volume of aggregate consumption, tends to rise with the combination of RDE openness and growth. Across regions, at least, this combination of changes appears Pareto-improving. The same is true of the volume measure of GDP, though the increases recorded in North America and the EU are imperceptible. And, not surprisingly, the combined shock raises the volume of exports everywhere. Among the OIEs, Australasia derives the most net benefit from RDE expansion, by virtue of its high trading intensity with RDE countries and its more substantial increase in agricultural production. Of course, it also undergoes considerably more structural change than do the other OIEs. North America and the EU experience only modest structural change, deriving little or no net benefit.

Finally, the factor market effects in the OIEs are summarized in Table 7.11. In general, their wage–rental ratios decline – more so against land, the

Table 7.10. *Percent Changes in Regional Welfare, GDP, and Exports*[a]

	Welfare (per capita)[b]		GDP		Exports	
	Open	Open with growth	Open	Open with growth	Open	Open with growth
Australasia	1.6	2.4	0.2	0.3	1.9	4.2
North America	0.4	0.5	0.0	0.0	1.8	4.3
European Union	0.7	0.7	0.1	0.0	0.7	4.3
Rapidly developing	8.7	40.4	10.9	59.7	45.3	84.4
Japan	1.9	2.4	0.1	0.1	1.2	9.7
Slowly developing	0.6	0.7	0.0	0.0	1.3	1.4

[a] Listed are proportional departures of scenarios 2 and 3 from the reference scenario (Table 7.8).
[b] A quantity index of per capita regional aggregate household consumption. See Chapter 2. No adjustment has been made for the changes of population implied in the growth shocks for the rapidly developing economies.
Source: Simulations of the GTAP model, as discussed in the text.

Table 7.11. *Changes in Relative Unit Factor Rewards in the OIEs*[a]

	North America		European Union		Australasia	
Percent Change in Unit Reward	Open	Open With Growth	Open	Open With Growth	Open	Open With Growth
1. Relative to the rate of return on capital						
Labor	-.7	-.10	-.06	-.06	-.38	.0
Land	1.16	8.28	-.95	2.02	.77	10.45
2. Relative to the CPI[b]						
Labor	.17	.29	.18	.24	.69	1.35
Land	1.39	8.67	-.70	2.32	1.85	11.81
Capital	.24	.38	.24	.30	1.08	1.36

[a] Listed are proportional departures of scenarios 2 and 3 from the reference scenario (Table 7.8), expressed as percentages of 1990 values.
[b] The CPI is a region-specific index of final consumption prices.
Source: Simulations of the GTAP model, as discussed in the text.

owners of which appear to be the principal OIE beneficiaries of RDE expansion. This is consistent with HOS model predictions. The further HOS prediction that labor would also lose relative to final product prices is not borne out, however. Comparisons with region-specific indices of final consumption prices show labor gaining in both scenarios 2 and 3, throughout the OIEs.[12] This confirms our expectation that the HOS effects would be diluted by the assumption that home products are differentiated from imports and by the aggregation bias effects associated with consolidating raw labor and human capital.

Again, because of its high trade intensity with the RDEs, Australasia stands out as showing substantially larger gains in real factor rewards. The advent of openness with growth in the RDEs makes capital considerably cheaper there, raising their output of minerals and processed raw materials. These sectors are unrestrained in the GTAP model by specific factors (such as mineral or energy deposits); therefore, they expand in competition with the capital-intensive minerals sector of Australasia. Thus, Australasia's expanding labor-intensive agriculture and contracting capital-intensive natural resource–based goods sector raises demand for labor relative to capital. It is therefore the only OIE group not experiencing an apparent fall in the wage–rental ratio due to RDE expansion. These effects are less significant for North America and the EU, since their natural resource–based goods sectors are much less important.

VI Inferring changes in the distribution of employment by occupation in the OIES

The consolidation of labor into a single factor in the GTAP model notwithstanding, it is possible to estimate shifts in labor demand across occupation by drawing upon separate data on the human capital content of the labor force in each industry. We have collected sufficient data to make it possible to split payments to labor by industry for the OIEs alone, though we have not used direct measures of human capital (such as years of education). Instead, we have used the International Labor Organization (ILO) standard occupational classification, which forms the basis of survey data on the skill composition of labor forces in all the OIEs, to divide payments to labor in each industry between a high-skill "more highly paid" category and a low-skill "less highly paid" category.[13] The results, which are summarized in Table 7.12, make it clear that manufacturing in the OIEs generally is intensive not only in labor but, more particularly, in low-skill labor.[14]

Applying this occupational distribution to the changes in generic labor use in each sector that emerge from the model simulations, we are able to estimate changes in employment, by occupation, which occur as a consequence of

Table 7.12. ***Occupational Shares (%) in Direct Payments to Labor in the OIEs*** [a]

	North America		European Union		Australia	
	More Highly Paid	Less Highly Paid	More Highly Paid	Less Highly Paid	More Highly Paid	Less Highly Paid
Crops	58	42	60	40	61	39
Other agriculture, forestry, and fishing	57	43	63	37	62	38
Mining	33	67	32	68	21	79
Highly capital-intensive manufacturing	23	77	25	75	17	83
Moderately capital-intensive manufacturing	41	59	33	67	27	73
Moderately labor-intensive manufacturing	29	71	25	75	20	80
Highly labor-intensive manufacturing	42	58	33	67	22	78
Petroleum and coal products	36	64	55	45	30	70
Labor-intensive services	41	59	42	58	41	59

[a] Based on the ILO Classification of Occupations, the more highly paid include managers and administrators, professionals, and paraprofessionals. The less highly paid include plant and machine operators and drivers, tradespersons, clerks, laborers and related workers, salespersons, and personal services workers.
Source: For the US: Bureau of the Census (1993); for the EU: Eurostat (1991a,b) and Ryan(1993); for Australia: Kenderes and Strzelecki (1993). The industrial classification in each case was concorded to the SALTER level (Hambley (1993)) prior to aggregation to the 10 sectors shown.

Table 7.13. *Percent Changes in Employment by Occupation, "Open High Growth" Over Reference Scenario*

	Agricultural	More Highly Paid[a]	Less Highly Paid[b]
North America	3.94	.00	-.07
EU	1.08	.05	-.07
Australasia	6.74	.52	-.27

[a] Managers and administrators, professionals, and paraprofessionals, as in Table 7.12, including more highly paid agricultural workers.
[b] Plant and machine operators and drivers, tradespersons, clerks, laborers and related workers, salespersons, and personal services workers, as in Table 7.12, including less highly paid agricultural workers.
Source: Estimates obtained by imposing the distribution of employment among occupations in the older industrial economies (Table 7.12) on the changes in generic labor use by industry emerging from the simulation.

openness and growth in the RDEs. If anything, this approximation underestimates the change in the distribution of employment across skill groups, since it assumes that employment composition within industries remains the same.[15] Given the broad industry groups adopted here, this is very unlikely. The results for the OIEs are given in Table 7.13. They show a tendency toward declining demand for low-skill workers and rising demand for high-skill workers. This contrast is strongest for Australasia, possibly because the industries that expand (agriculture and services) tend to use skilled labor, while the sectors that decline (natural resource–based products and manufacturing) are intensive in unskilled labor.

VII Conclusion

The opening and rapid expansion of Asian developing countries is examined for its effects on the OIEs. Although the process is found to cause substantial changes in the structure of the OIE economies, none appears to suffer reduced economic welfare or GDP as a consequence. The resulting surge of labor-intensive exports from the RDEs does have unequal effects on workers and the owners of capital and land, however. The wage–rental ratio declines throughout the OIEs, and more so relative to land rents.

This inequality notwithstanding, all unit factor rewards rise relative to final consumption prices in all the OIE regions. Their economies enjoy a favorable shift in their terms of trade and increased consumer demand, which tends to mitigate the effects on demand due to cheaper imports. And, in any case, the labor (including human capital) share of value-added in their export industries tends to be just as high as in those that compete with Asian imports. Nevertheless, we present evidence that the results imply a shift in the composition of labor demand in the industrial economies against low-skill workers and hence; had we been able to disaggregate the labor force by skill level,[16] low-skill workers might have appeared as losers from Asian economic reform and growth.

This analysis is constrained somewhat by the structure of the existing GTAP data base and model. While its strength lies in its representation of the reciprocal nature of international trade, so that the RDEs are both competitors and customers of the OIEs, the weakness of the current version is that its data base does not capture the dispersion of skill and capital intensities across industries. (See Chapter 14 for an early attempt at remedying this deficiency.) In the OIEs, the apportionment of value-added between generic labor and other factors seems similar in light and heavy manufacturing. Yet separate evidence indicates that their skill mixes differ substantially. Disaggregation by skill level would therefore greatly improve the model's representation of factor markets. Further, the disaggregation of households in each region between those supplying unskilled labor, on the one hand, and those supplying human or physical capital, on the other, would provide scope to capture the effects of different preferences between winners and losers on derived labor demand.[17]

NOTES

1. The interested reader is referred to Chapter 2 for more detail on the specification of the model.
2. Of course, some nonhomotheticity is already built into the GTAP constant difference of elasticities (CDE) demand system, which is described in Part II.
3. As is common with such models (Brown and Stern 1989), results tend to be critically sensitive to the estimates of elasticities of substitution in demand that are used. Indeed, when these elasticities are in the range commonly estimated (1–5), large-country effects are prominent and income changes dominate relative price shifts in determining the mix of consumption among home goods and imports. In this framework, trade reform can move border distortions away from their optimal levels for some countries and have little effect in switching domestic demand toward imports. Some recent studies have suggested, however, that the common range of estimates of elasticities of substitution in demand is too low (Horridge 1987; Tyers et al. 1996).
4. This pattern is exhibited by US data presented in Leamer (1993). The difference in the occupational pattern between the four types of manufacturing is substantial, however, as indicated later, in Table 7.12.
5. In this analysis, we ignore errors in the use of market exchange rates as weights in international comparisons. The use of weights based on purchasing power parity (PPP) makes an especially large difference in the case of China. When these are used, China's share of world GDP by 1990 is raised from 2% to over 6% (IMF 1993, Annex IV). By contrast, that of Japan is reduced from 17% to only 8%.
6. The regional aggregation chosen tends to hide similar transformations in some other developing countries during this period. The large change in China's openness would be moderated somewhat were its GDP measured assuming PPP.
7. The trade contrast is better drawn in an earlier version of this chapter [McDougall and Tyers (1993), table 7], which showed that "heavy manufactures" dominate RDEs imports.
8. Scenario 1 is derived by forcing on the RDEs a level of openness equivalent to what they would have achieved had they opened at the rate of the OIEs over

1970–1990. This required the imposition of a generic 170% increase in the power of their 1990 tariffs (the resulting ratio of domestic to border prices, controlling for marketing margins). Barriers thus enlarged are removed in scenarios 2 and 3.

9. To see this, note that the average real growth in GDP achieved in the OIEs between 1970 and 1990 was approximately 74%. The growth achieved by the RDEs was 333%. Had the RDEs grown as slowly as the OIEs in that period, their 1990 GDP would have been smaller by 100 (433 – 174)/433 = 60%. This is the precise gain that scenario 1 yields.
10. It is likely that the observed difference in growth rates has been due to a combination of trade barrier reductions and technical change, where the technical change is distributed unevenly across both sectors and factors. New information is required before realistic shocks of this type can be constructed.
11. As stated in note 5, above, this is probably an underestimate.
12. In North America particularly, the net gains in all factor prices relative to final product prices contrast with the negligible gains in GDP and welfare indicated in Table 7.10. This suggests that the structural change there supports subsidized industries (e.g., agriculture), reducing allocative efficiency. Factor income gains are offset by net reductions in the revenue from indirect taxes.
13. We avoided human capital measures because of their lack of homogeneity. Their use tends to inflate the skill content of the labor force relative to the use of occupational criteria. The occupational data also have their biases, however. In particular, the predominance of the self-employed in agriculture tends to lead to the classification of a disproportionate share of the rural population as "managers." This is evident from the first two rows of Table 7.12, which show agriculture to be intensive in "more highly paid" workers.
14. The largely nontraded labor-intensive services sector, however, appears to use mostly high-skill workers. This is very likely a property of the skill mix in OIEs that does not extend to the developing countries.
15. That changes in factor proportions have occurred within industry is confirmed for the US by Berman et al. 1994.
16. This result is reported in McDougall and Tyers (1994).
17. It should be noted that the analysis of Australasian factor markets in the face of Asian growth is impaired by the lack of any specific factor (mineral, energy, or other fixed resource) to constrain the response of the mining and petroleum and coal industries' responses to changes in the cost of capital. This tends to enhance the expansion of this sector with growth in Asia to an unrealistic extent, weakening the analysis of trade with Australasia, where that sector tends to dominate exports.

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CHAPTER 8

An evaluation of the Cairns Group strategies for agriculture in the Uruguay Round

Donald MacLaren

I Introduction and overview

The scope of the agenda for the agricultural trade negotiations in the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) was influenced to a considerable degree by the coalition known as the Cairns Group, an agenda-moving group that succeeded in subjecting its domestic agricultural policies to international negotiation.[1,2] This initial outcome of the coalition's activities was a significant achievement and a departure from the agricultural agenda in previous negotiating rounds, an agenda that had been deficient because the contracting parties had avoided the issue of domestic agricultural policies.[3] The main leadership of the group has been, and continues to be, provided by Australia. In the four years following that country's petulant behavior at the GATT Ministerial Meeting in 1982, a more positive attitude was adopted toward international diplomacy in the area of agricultural trade policy, for example, by producing the so-called Red and Gold books, thereby bringing into the public domain an evaluation of the self-inflicted economic harm done by agricultural policies.[4] Hence, at Punta del Este in 1986, the Cairns Group was able to help establish, through skillful diplomacy with the US and the European Union (EU), the agenda for the agricultural negotiations.[5]

During the negotiations, the coalition maintained substantial and unified pressure on these major players. This, in itself, was an achievement because, since the group's inception, there had been internal tensions within it: between "North" and "South" over the issue of services, and between Canada and Australia over agricultural policy matters. Canada, although being party to the Cairns Group submission to the GATT in 1987, insisted on submitting its own national views because these were not wholly consistent with those of its partners, and in particular Australia's. These obvious tensions arose between the two countries partly because of traditional differences in the style of diplomacy pursued and partly because of differences in their definition of the basic underlying goal of agricultural policy reform (Higgott and Cooper 1990; Cooper 1992).

Throughout the round, it was apparent that Canada was more accommodating toward domestic agricultural policies and the associated income objectives for the farm sector, and it continued to subsidize its agriculture and to insist on maintaining the supply management regimes for dairy and poultry products. On the other hand, after 1983, the commonwealth government in Australia sought to deflect the political costs of deregulating the agricultural sector, to the extent permitted by constitutional constraints, by promulgating the view in the rural sector that multilateral trade reform would more than compensate for a reduction in commonwealth government assistance (Higgott and Cooper 1990). The Canadian government did not follow this lead and has been more sensitive politically to the issue of farm incomes (Cooper 1992).

As the round dragged on, the Cairns Group, as reflected in the utterances of the Australian government, became more strident in its criticism of the stances taken by both the US and the EU on the reform of their agricultural policies. This increased stridency reflected, no doubt, the increasing frustration felt by the group that, once again, any final deal on agriculture was in danger of being negotiated bilaterally between the US and the EU, the very outcome that the Cairns Group had been established to prevent. That frustration was justified because at the important Blair House Accord between the US and the EU in November 1992, the Cairns Group was not a participant. On balance, the EU was the main target of Australian criticisms, the belief being that the Common Agricultural Policy is more destructive of the well-being of the Australian farm sector, of the national economy, and of international agricultural trade in general than are the agricultural policies of the US.[6]

The purpose of this chapter is twofold. The first objective is to investigate quantitatively the individual gains to Australia and to Canada of unilateral agricultural trade liberalization by the US and the EU. By measuring the gains to each of Australia and Canada, it will be possible to determine whether the Cairns Group was correct in supporting the Australian position of attacking the Common Agricultural Policy more than the agricultural policy of the US. The second objective is to measure the distributional effects of agricultural policy liberalization within Australia and Canada. By quantifying the effects of their unilateral liberalization, it will be possible to determine whether political sensitivity to farm incomes had a sound economic foundation in political economy.

II Aggregation

For purposes of this chapter, the Global Trade Analysis Project (GTAP) data base was aggregated to six regions: Australia, Canada, the US, Japan, the EU, and the rest of the world (ROW). Because version 2 of the data base does not identify all the Cairns Group countries individually, and because agriculture appears to be of greater concern to Australia and Canada than to the South American and Association of South East Asian Nations (ASEAN) members of the group, the Cairns Group countries, minus Australia and Canada, could not be aggregated into a separate region. An alternative to the aggregation chosen would have been to consider the effects of the Cairns Group strategy on the major subgroups within the group and to evaluate the North–South tensions over services together with those for agriculture. However, the policy simulations are restricted to those involving the agenda for agriculture; therefore, only the two countries of interest within the group – namely, Australia and Canada – are identified separately. This is also why the commodity aggregation is heavily agriculture-focused, breaking out: wheat, other grains, wool, rice, meat products, milk products, other agricultural and food products, manufacturing and services.[7]

Agriculture and food are important sectors in all the regions identified. This is particularly true for Australia, where food's contribution to export earnings is one of the highest in the industrialized world. For that reason the model was run with a general equilibrium closure. The basic production data from the aggregation of countries and commodities are shown in Table 8.1. There are considerable differences among the regions with respect to the relative importance of the separate commodity aggregates. For example, wool is very important to Australia, but less so to the other regions. Rice stands out in Japan, as do grains in the US and Canada.

The patterns of gross exports in tradeable products are shown in Tables 8.2 and 8.3. (The emphasis on exports rather than on imports should not be interpreted as mercantilist; rather, it reflects the concern of the Cairns Group for improved market access, and for less distorted international markets for agricultural products.) For Australia (Table 8.2), the EU (at 15%) is a more

Table 8.1. ***Value of Sectoral Output (1992 $US million)***

	Australia	Canada	USA	Japan	EU	ROW
Wheat	2,037	5,564	22,652	4,583	38,572	32,807
Other grains	707	3,295	44,697	7,041	32,210	103,436
Wool	3,393	2	236	7	1,004	3,932
Rice	350	85	5,547	76,010	6,991	249,910
Meat products	7,558	12,858	79,822	32,953	179,362	152,969
Milk products	4,002	8,256	47,855	19,803	112,971	46,409
O. Ag. and food	30,601	57,712	469,736	408,465	881,982	1,090,260
Mnfc and Svces	455,710	1,005,880	8,951,790	6,184,810	9,987,410	9,171,640

Source: GTAP data base.

Table 8.2. *Pattern of Australia's and Canada's Agricultural Exports (fob basis)*

	Australia	Canada	US	Japan	EU	ROW	Total
			Share of Total, %				$US m
Wheat							
Australia	0	0	0	15	0	85	1,200
Canada	0	0	5	8	3	84	3,986
Other grains							
Australia	0	0	0	29	2	69	354
Canada	0	0	21	24	4	51	643
Wool							
Australia	0	0	4	17	38	40	2,834
Canada	0	0	100	0	0	0	1
Rice							
Australia	0	0	0	0	15	85	93
Canada	0	0	0	0	0	100	1
Meat products							
Australia	0	4	33	35	5	23	2,625
Canada	1	0	67	18	6	8	931
Milk products							
Australia	0	0	2	20	2	76	676
Canada	1	0	10	9	15	65	157
O. Ag. and food prod.							
Australia	0	3	5	24	12	56	3,499
Canada	1	0	60	14	12	13	6,211
Total							
Australia	0	2	10	23	15	49	11,281
Canada	1	0	39	13	8	39	11,930

Source: GTAP data base.

important destination for exports than is the US (10%), even with trade-distorting agricultural policies in place. However, ROW (49%) and Japan (23%) are even more important. For Canada (Table 8.2), the US (39%) and ROW (39%) are equally important and easily dominate the EU (8%) and Japan (13%) as export destinations. This base period information provides insight into the differences between the Australian and Canadian positions and into their respective sensitivity to the US and the EU. These data are also important in understanding the outcomes of the unilateral trade liberalization experiments for the US and the EU as demonstrated in section IV below. For

Table 8.3. *Pattern of US's and EU's Agricultural Exports (fob basis)*

	Australia	Canada	USA	Japan	EU	ROW	Total
	Share of Total, %						$US m
Wheat							
US	0	0	0	14	2	83	4,219
EU	0	0	0	0	0	100	1,269
Other grains							
US	0	1	0	30	6	63	6,465
EU	0	0	0	3	0	97	783
Wool							
US	0	0	0	8	54	38	13
EU	5	1	5	35	0	53	110
Rice							
US	0	6	0	0	21	73	923
EU	0	0	2	0	0	97	243
Meat products							
US	0	12	0	49	5	34	4,431
EU	0	0	7	19	0	73	3,865
Milk products							
US	1	6	0	6	2	85	410
EU	1	1	6	4	0	88	4,701
O. Ag. and food prod.							
US	1	11	0	18	25	45	30,821
EU	1	3	17	8	0	71	30,671
Total Exported to							
US	1	9	0	22	18	51	47,282
EU	1	2	14	8	0	75	41,642

Source: GTAP data base.

the US (Table 8.3), ROW (51%) is the most important destination, with Japan (22%) and the EU (18%) almost equally important. The pattern of EU exports is more concentrated, with 75% of exports going to ROW (Table 8.3) and only 14% destined for the US; Australia and Canada are insignificant export destinations.

III Experimental design

The experiments in this chapter were designed to help evaluate two strands in the Cairns Group strategy for negotiating reforms in agriculture as part of the Uruguay Round in the GATT. The first strand reflects the group's concentration on the damage done to international agricultural trade and, hence their economies, by the EU's Common Agricultural Policy (CAP). The second strand reflects the different treatment of agriculture by the governments of Australia and Canada: the former trying to convince those in the agricultural sector that the short-run pain created by deregulation of the sector would be more than offset by the longer-term gains from multilateral agricultural trade liberalization; the latter country remaining much more susceptible to lobbying by those in its agricultural sector.

The policy experiments run are as follows.

- Experiment 1 (E1) considers the unilateral removal of domestic agricultural policy instruments and agricultural trade policy instruments by the US without adjustment for the existence of set-aside. It is assumed that such set-aside land is prevented from reentering production by means of an expanded conservation reserve program. Also, the EU is assumed to insulate its agricultural sector. This is achieved on the import side by swapping *pr(i,e_u)*, the price ratio of imports to domestic goods, with *tm(i,e_u)*, thereby mimicking the variable levy. On the export side, *tx(i,e_u)* is permitted to vary, and output *qo(i,e_u)* is fixed. This mimics the workings of the variable export subsidies. [See Hertel, Gehlhar, and McDougall (1994) for more details on this closure.]
- Experiment 2 (E2) simulates unilateral agricultural domestic and trade liberalization by the EU through removal of the CAP and without its replacement by national agricultural policies.
- Experiment 3 (E3) examines unilateral removal of domestic agricultural policies and agricultural trade policies by Australia. The EU insulates its agricultural sector.
- Experiment 4 (E4) simulates unilateral removal of domestic agricultural policies and agricultural trade policies by Canada. The EU insulates its agricultural sector.

The first objective is evaluated through a comparison of results of experiments 1 and 2; an evaluation of the second objective requires a comparison of the results of experiments 3 and 4, followed by a comparison with some of the results of experiments 1 and 2.

These four experiments, although none of them are novel, have not been conducted before in the context of assessing the political economy of the Cairns Group negotiating strategy. The outcomes are studied from the Australian and Canadian perspectives within the context of the Cairns Group coalition of self-styled "fair trading" agricultural exporting countries. Since the mid-1980s, a substantial literature has developed in which the results of simulation experiments involving the liberalization of agricultural policies have been published. In previous studies the focus has been largely on the effects of industrialized country liberalization or world liberalization on regional and world welfare [see, e.g., Anderson and Tyers (1991); Blandford (1990); Goldin, and Knudsen (1990); Meilke (1987); Nguyen, Perroni, and Wigle (1993); OECD (1990); and Tyers and Anderson (1992)]. In addition, many studies have paid attention to the US and EU economies and the effects of agricultural trade policy liberalization on each other [see, e.g., Commission of the European Communities (1988)]. In some of these latter studies, a Nash outcome to the negotiating game has been formally derived [see, e.g., Johnson, Mahé, and Roe (1993)]. A number of studies have focused on liberalization by a single country [see, e.g., Stoeckel and Breckling (1989) for the EU; Vincent (1989) for Japan; Hertel, Thompson, and Tsigas (1989) for the US; and Higgs (1989) for Australia] and on the political economy of agriculture in the GATT [see, e.g., Avery (1993)]. By contrast, in the experiments described in this chapter, the motivation is provided by political economy and, in particular, an evaluation of the strategy adopted by the Cairns Group as reflected in the positions of Australia and Canada.

IV Results

A subset of the policy liberalization shocks administered in E1–E4 are reported in Tables 8.4 and 8.9. These involve removal of policies relating to taxes on agricultural output (*to*), agricultural export taxes (*txs*), and agricultural import tariff and nontariff equivalents (*tms*) in the unilaterally liberalizing region. (In order to conserve space, bilateral export and import shocks are reported only for ROW; these are indicative of the shocks to rates for other regions.) Entries in the vector of shocks *to* that are negative indicate that a subsidy is to be removed so that the domestic producer price will fall. Conversely, a positive entry denotes elimination of a net producer tax. Negative (positive) entries in the vector of shocks *tms* indicate that a border import tax (subsidy) is to be removed. This lowers (raises) domestic market prices. In the case of the vector *txs*, negative (positive) entries indicate the removal of an export subsidy (tax), which depresses (raises) domestic prices relative to world prices.

Experiment 1: Liberalization by the US

The shocks required for US agricultural trade liberalization, as outlined above, are shown in Table 8.4. It is noticeable that the pattern of support between domestic and trade instruments varies considerably across the eight commodities and underlines the comment made above that for certain commodities, earlier negotiations on agriculture in the GATT had missed the main source of trade distortions. The most heavily distorted products in terms of domestic

Table 8.4. *Percentage Shocks[a] for Complete US and EU Agricultural Policy Liberalization*

	Domestic Output (to)	Exports to ROW (txs)	Imports from ROW (tms)
Wheat			
US	-24.5	-16.7	-9.2
EU	-5.9	-67.6	-33.9
Other grains			
US	-23.4	-1.3	-3.4
EU	-2.4	-70.7	-40.3
Wool			
US	-38.7	0.0	-4.9
EU	-0.4	-0.0	-0.7
Rice			
US	-24.4	-1.6	-4.2
EU	-2.2	-25.4	-56.3
Meat products			
US	0.3	-1.5	-15.4
EU	-0.2	-44.8	-35.9
Milk products			
US	-4.1	-34.1	-49.9
EU	0.4	-47.8	-57.1
O. Ag. and food prod.			
US	2.7	-0.0	-8.7
EU	-9.3	1.6	-28.2

[a] Shocks for import and export policies are restricted to the region ROW only for considerations of space. but they are indicative of the shocks for the other regions.
Source: GTAP data base.

subsidy instruments are wheat, other grains, wool, and rice (large negative entries in *to*), while meat products are taxed rather than subsidized under existing policies. Products most supported through export subsidies are wheat and milk products (negative entries in *txs*), while those most protected from imports are meat products and milk products (negative entries in *tms*).

Only a few of the important features of the outcome of this simulation will be analyzed and presented here. The results for the variable *qo*, the percentage change in the quantity of sectoral output, are shown in Table 8.5, together with the corresponding changes in the volume of output.[8] There are important falls in the volume of US production of wheat (24%, $US 4,129m) and of other grains (11%, $US 3,623m). There are also substantial percentage falls in the outputs of the less important products (see Table 8.1), namely, wool (49%) and rice (21%). For meat products, milk products, and other agricultural and food products the percentage reductions are small: they amount to $US

Table 8.5. ***Liberalization of US (E1) and EU* (E2) Agricultural Policies: Changes in Volume Output (1992 $US million; percentage change in volume in parentheses)***

	Australia	Canada	US	Japan	EU	ROW
Wheat						
E1	363 (19)	1,358 (29)	-4,129(-24)	864 (22)	0 (0)	2,832 (9)
E2	120 (6)	677 (14)	1,229 (7)	65 (2)	-7,830 (-22)	1,713 (5)
Other grains						
E1	110 (16)	428 (14)	-3,623(-11)	1,197 (20)	0 (0)	4,694 (4)
E2	29 (4)	139 (5)	1,753 (5)	87 (2)	-7,409 (-24)	3,549 (3)
Wool						
E1	19 (1)	0 (18)	-71(-49)	0 (1)	0 (0)	62 (2)
E2	-12 (-0)	0 (3)	4 (3)	0 (5)	38 (4)	36 (1)
Rice						
E1	18 (5)	16 (19)	-890(-21)	-222 (-0)	0 (0)	1,131 (0)
E2	46 (13)	2 (2)	643 (15)	15 (0)	-2,465 (-36)	3,815 (1)
Meat products						
E1	215 (3)	155 (1)	-694 (-1)	-195 (-0)	0 (0)	128 (0)
E2	597 (8)	241 (2)	1,432 (2)	324 (1)	-16,494 (-9)	8,039 (5)
Milk products						
E1	166 (4)	162 (2)	-2,131 (-5)	0 (0)	0 (0)	1,472 (3)
E2	812 (19)	569 (7)	837 (2)	292 (2)	-16,796(-15)	8,864(20)
O. Ag. and food prod.						
E1	91 (0)	1,348 (2)	-4,646 (-1)	-2,982 (-1)	0 (0)	1,096 (0)
E2	1,386 (5)	1,175 (2)	10,747 (2)	635 (0)	-115,612 (-14)	58,057 (5)
Manuf. and services						
E1	-1,036 (-0.2)	-3,589 (-0.3)	11,533 (0)	-1,723 (-0)	0 (0)	-13,984(-0)
E2	-2,127 (-0)	-2,446 (-0)	-10,479 (-0)	-834 (-0)	128 399 (1)	-77,513(-1)

Source: GTAP simulation
* The EU is assumed to insulate its agricultural sector in this simulation.

694m, $US 2,131m, and $US 4,646m, respectively. The contractions in the output of the US agricultural sector are mirrored by an increase in manufacturing and service sector output of $US 11,533m. These changes in the output mix of the US economy, in general, affect world prices, trade flows, and output in other regions.[9] The magnitude of these changes in average world prices, by commodity, is shown in Table 8.6. The international price effects are greatest for cereals (wheat 14.3%, other grains 15.2%, and rice 6.3%) and for milk products (4.8%). The directions of these effects are consistent with expectations, and their magnitudes are consistent with the relative sizes of the liberalization shocks.

Table 8.6. *Liberalization of Agricultural Policies: Changes in World Prices Indices [pxwcom(i)]*

	E1	E2	E3	E4
Wheat	14.3	5.6	0.1	5.4
Other grains	15.2	3.9	0.0	1.0
Wool	1.3	2.2	0.9	0.3
Rice	6.3	3.1	0.0	0.1
Meat products	0.5	7.0	-0.2	1.0
Milk products	4.8	21.6	1.2	2.1
O. Ag. and food prod.	0.3	2.0	0.0	0.2
Manuf. and services	-0.0	0.2	0.0	-0.0

Source: GTAP simulation.

As shown in Table 8.5, for Australia the largest percentage changes occur in the outputs of wheat (19%) and other grains (16%), which amount to \$US 363m and \$US 110m, respectively. Small increases are shown for rice (5%), meat products (3%), and milk products (4%), amounting to \$US 18m, \$US 215m, and \$US 166m, respectively. The increases in agricultural output are accompanied by a reduction in the value of output of the manufacturing and services sector (–0.2%, or \$US 1,036m). A similar pattern emerges for Canada, with wheat outputs increasing by 29% (\$US 1,358m) and other grains by 14% (\$US 428m), and the manufacturing and services sector contracting in value by –0.3%, or \$US 3,589m.

It should be noted that there are no changes in agricultural output in the EU because the insulating effect of the threshold price/variable levy system of the CAP prevents changes in international prices from affecting domestic agricultural markets. However, there are budgetary consequences for the EU as world prices rise for its imports from major suppliers (these are not shown here but are found in the matrix *pcif(i,r,e_u)*). This same qualitative picture emerges from noting the changes in the global price indices by commodity, *pxwcom(i)*, reported in Table 8.6. Here we see price increases ranging from 0.5% for meat products to 15.2% for other grains. This increase in world prices also causes EU expenditures on export subsidies to fall. These decreases range from 0.3% for other agricultural and food products to 6.3% on milk products and 8.8% on wheat, and may be found in the vector *tx(i,e_u)* (not reported here).

The focus of the Cairns Group was on the removal of policies that distort agricultural trade. Therefore, it is important to consider the changes in export volume stimulated by the removal of US policies and to *calculate the resulting benefits to Australia and Canada*. The percentage changes in bilateral trade are obtained from the variable *qxs(i,r,s)*. This information, together with base period flows at market prices, *VXWD(i,r,s)*, enable us to calculate the changes in volume of exports by region r to all other regions, at base period market prices. Results are shown in Table 8.7. The greatest differences between the two countries in exports of agricultural and food products are in exports of

Table 8.7. ***Impact of Liberalization of US and EU Agricultural Policies on Exports Volumes from Australia and Canada***

	Australia		Canada	
	%	$US m	%	$US m
Wheat				
E1	*30.3*	356	*31.3*	1344
E2	*7.2*	85	*15.6*	670
Other grains				
E1	*30.1*	105	*41.6*	315
E2	*4.5*	16	*11.7*	88
Wool				
E1	*0.7*	21	*18.1*	0
E2	*-0.3*	-9	*3.3*	0
Rice				
E1	*14.4*	13	*41.2*	1
E2	*35.4*	33	*36.2*	1
Meat products				
E1	*7.7*	202	*16.0*	149
E2	*20.8*	544	*21.4*	200
Milk products				
E1	*16.3*	132	*35.3*	99
E2	*80.4*	653	*139.7*	392
O. Ag. and food prod.				
E1	*-1.3*	-44	*18.1*	1139
E2	*17.9*	624	*8.2*	514
Manuf. and services				
E1	*-1.7*	-634	*-1.7*	-2264
E2	*-3.6*	-1371	*-1.1*	-1499

Source: GTAP simulation.

wheat and other agricultural and food products, from which Canada gains over $US 1 billion in each case, whereas Australian exports increase for wheat but decline by $US 44m for other agricultural and food products. Part of the explanation is that 60% of Canada's exports of other agricultural and food products goes to the US as compared with only 5% for Australia (Table 8.2) and the output of other agricultural and food products in the US has fallen by $US 4646m (Table 8.5).

Finally, the increase in the real price of the sector-specific asset, agricultural land, in Australia and Canada can be used as a proxy for the change in producer surplus. This information is useful in the second set of experiments, in which the political economy of unilateral removal of protectionism by these countries is investigated. Using the base period value of land (*EVOA*), the percentage change in the agents' price of land (*ps*), and the percentage change in the price index of private household expenditure (*ppriv*) as the deflator, the real increase in producer surplus in Australia is $US 265m and in Canada is $US 604m (Table 8.8). Overall, national welfare, as measured by equivalent variation, increases in Australia and Canada by $US 389m and $US 458m, respectively.

Experiment 2: Liberalization by the EU

The shocks required to remove the domestic and trade policy instruments associated with the EU's CAP are presented in Table 8.4. The size of the shocks to remove the domestic instruments are relatively small (*to*); it should be remembered that income support for the farm sector in the EU, unlike the position in the US, comes largely from transfers from consumers rather than from taxpayers [see Blandford (1990), p. 406]. Therefore, the shocks required to remove the insulating trade policies, that is, the export subsidies (*txs*) and the import levies (*tms*), are substantial. Output of the milk products sector is taxed (the entry in *to* is positive) rather than subsidized, and exports of other agricultural and food products are also taxed (the entry in *txs* is positive) and not subsidized. For all other products, the signs of the shocks indicate a removal of output subsidies, export subsidies, and import taxes. In comparing the shocks for the EU with those for the US (Table 8.4), it would appear that, in general, much more support for US agriculture comes from domestic instruments, except for livestock products, whereas in the EU, the support is through the use of import barriers and aids to exports. However, the size of the shocks on their own does not lead to an inference about the disruptive effects of the CAP on international trade; changes in trade volumes and world prices are also required.

Selected results of this policy experiment are as follows. The outputs of the agricultural sector of the EU contract, as anticipated (Table 8.5). The largest percentage reductions occur in grains: wheat –22%, other grains –24%,

Table 8.8. ***Summary Measures of Agricultural Policy Liberalization***

	E1	E2	E3	E4
	Equivalent Variation ($US m) [EV(r)]			
Australia	389	811	-0.7	133
Canada	458	254	-1.3	814
US	3,193	1,210	-20.0	175
Japan	-3,456	1,662	-73.0	-588
EU	414	7,120	83.1	240
ROW	-2,626	15,106	-77.2	-752
World	-1,628	26,162	-89.1	20
	Producer Surplus ($US m)[a]			
Australia	265	322	-86	72
Canada	604	306	3	-927
US	-1525	1009	6	325
Japan	837	110	5	109
EU	0	-5863	0	0
ROW	2516	11213	53	452
	Terms of Trade (%) [psw(r) - pdw(r)]			
Australia	0.5	1.1	0.0	0.2
Canada	0.5	0.4	0.0	-0.3
US	0.0	0.4	0.0	0.1
Japan	-0.1	0.2	0.0	0.0
EU	0.0	-1.6	0.0	0.0
ROW	0.0	0.7	0.0	0.0

[a] The change in producer surplus is approximated as the change in the value of the sector-specific asset, land deflated by the price index [*ppriv(r)*].
Source: GTAP simulation.

and rice –36%. However, in volume terms the greatest effects of liberalization occur in the livestock sector, with the volume of production of meat products falling by $US 16,494m and milk products by $US 16,796m. There is also a substantial decline in other agricultural and food products of $US 115,612m. As EU agriculture contracts, resources become available to enable the nonagricultural sectors to expand; manufacturing and services do so by $US 128,399m. The international price effects of the liberalization of the CAP are not as dramatic as those that might have been anticipated and, with the important exception of milk products, are generally smaller than those generated by liberalization of US agricultural policy (Table 8.6). This finding must be qualified by noting that E1 does not account for the price dampening effect of possible reentry of set-aside land in the US. Also, it is the result of the *price insulating* effects of the CAP, as implemented in E1. Because the EU does not participate in the adjustment to higher world prices, a greater movement in price is required to attain a new equilibrium.

Column two of Table 8.5 shows that Australian agriculture benefits from EU agriculture liberalization, particularly in other agricultural and food products ($US 1,386m), milk products ($US 812m), and meat products ($US 597m). The wheat sector makes a small gain of 6%, or $US 120m, and the wool sector contracts by $US 12m. Mirroring the expansion in agriculture is the contraction in manufacturing and services of $US 2,127m. In Canada, the wheat sector benefits most in percentage terms (14%), but in volume terms the greatest gain is in other agricultural and food products ($US 1,175m). The output of the livestock sector expands with meat products growing by ($US 241m) and milk products by $US 569m. The Canadian manufacturing and services sector contracts by $US 2,446m.

With the trade distorting instruments of the CAP removed, Australian and Canadian exports of agricultural products expand. The changes in the volume of exports are obtained as before and are presented in Table 8.7. For Australia, exports of all agricultural products increase, with the exception of wool – the increases being greater than those reported for E1 for livestock products but less than those for wheat and other grains. At the same time, there is a loss of exports in manufacturing and services of $US 1,371m. On the other hand, Canadian exports of manufacturing and services fall less in this experiment than in the previous one. The offsetting gains in wheat and in other agricultural and food products are about one half as large as those obtained in E1, while those for livestock products are substantially greater.

The gains in the Australian and Canadian agricultural sectors, as measured by the increase in the real value of sector-specific assets, are shown in Table 8.8. For Australia, producer surplus increases by $US 322m, while Canada shows an increase of $US 306m. However, in terms of national welfare, Australia gains by $US 811m, and Canada gains by $US 254m.

Evaluation of the first objective. The first objective of this chapter was to determine whether the political rhetoric of the Cairns Group with respect to the relative distortions created by the agricultural policies of the US and the EU has a basis in economics. These policies, once liberalized unilaterally, generate a different set of international prices, thereby altering output levels as well as the pattern of trade flows. Unilateral liberalization by the US has a greater effect on world prices for grains than for livestock products: the effects of removing the CAP are the reverse (Table 8.6).

The overall changes in welfare in each of the six regions are provided by the equivalent variation (Table 8.8). There are a number of interesting features in this table. First, there are gains to Australia, Canada, and the US, as expected, and a small gain to the EU following unilateral liberalization of US agricultural policies. Second, there are large losses to Japan, which, as a net importing region of agricultural and food products, loses from higher world prices for these products, and loses further from the fall in the world price of manufactures and services. Hence, Japan's terms of trade decline by 0.1%. Third, there is a loss to world welfare from US liberalization. This is a *second-best* result that follows from the fact that the rise in world prices causes other regions (e.g., Japan) to exacerbate their misallocation of resources. It also depends critically on the assumptions of no change in US set-aside land and EU insulation. Fourth, the changes in regional welfare generated by removal of the CAP are quite different. The welfare gains to Australia are positive ($US 811m) and greater than they were in E1, whereas the gain to Canada ($US 254) is less than in the first experiment. As expected, there are large gains in the EU. ROW gains due to its dominant role as an exporter of agricultural products into the EU and as an importer of manufactures and services from the EU. [See also Hertel, Gehlhar, and McDougall (1994) on this point.] Finally, there is a net gain of $US 26 billion across all regions. This contrasts with the loss of $US 1.6 billion in E1.

From the changes in real income, as measured by equivalent variation, it is clear that for Australia the CAP depresses regional income more than the agricultural policy of the US, that is, by $US 811m as compared with $US 389m, respectively. For Canada, the reverse is true, with US policy depressing real incomes by $US 458m, as compared to $US 254m owing to the existence of the CAP. Moreover, the improvement in Australia's terms of trade under E2 (1.1%) exceeds that achieved under E1 (0.5%), while for Canada, the improvement under E1 (0.5%) exceeds that under E2 (0.4%) (Table 8.8).

The political stance of the Cairns Group in supporting Australia's concentrated attack on the CAP is partially vindicated by the results of these two simulations. Moreover, by focusing on liberalizing the CAP, the Cairns Group was assisting in raising world real income. But the greater caution Canada demonstrated with respect to the agricultural policies of the US and the EU is also shown to be justified and helps to explain, in part, the tension between Australia and Canada within the Cairns Group that arose over agricultural policy.

Experiment 3: Liberalization by Australia

The second objective in this chapter was to explore the distributional effects of unilateral liberalization of agricultural policies within Australia and Canada, and to compare these outcomes with the income effects created by unilateral liberalization by the US and the EU. It is then possible to assess the political judgments made by the governments of Australia and Canada with respect to deregulation of their respective agricultural sectors. The Australian government has chosen to ignore the farm lobby, while the Canadian government has continued to pursue its objective of supporting farm incomes. This set of experiments focuses on changes in producer surplus and national welfare.

Australia's removal of domestic agricultural policies and trade policies requires the shocks shown in the upper entries of Table 8.9. These are of a

Table 8.9. ***Percentage Shocks[a] for Complete Australian and Canadian Agricultural Policy Liberalization***

	Domestic Output (to)	Exports to ROW (txs)	Imports from ROW (tms)
Wheat			
Australia	-3.9	2.1	-0.2
Canada	-14.4	-7.1	-22.4
Other grains			
Australia	-3.5	2.2	-1.8
Canada	-7.1	-15.1	-12.7
Wool			
Australia	-3.2	1.3	-2.0
Canada	-3.3	0.0	-2.2
Rice			
Australia	-0.8	0.2	-4.2
Canada	0.3	0.0	-1.0
Meat products			
Australia	0.7	0.5	-5.6
Canada	-18.0	0.0	-18.0
Milk products			
Australia	6.0	-16.7	-25.9
Canada	-4.3	-44.1	-57.5
O. Ag. and food prod.			
Australia	-0.3	0.5	-4.7
Canada	-2.3	-1.4	-6.6

[a] Shocks for import and export policies are restricted to the region ROW only for considerations of space but they are indicative of the shocks for the other regions.
Source: GTAP simulation.

much smaller order of magnitude than the shocks presented above for the US and the EU (Table 8.4). Domestic assistance (indicated by negative entries shocks *to*) is provided for all products except for meat products and milk products, which are taxed. Exports are taxed (the entries in *txs* are positive) with the exception of milk products which are subsidized. Imports are all taxed, with milk products receiving the greatest protection (the entries in *tms* are negative).

Removal of the policies implicit in the shocks shown in Table 8.9 result in adjustments in Australian output, exports, and imports (Table 8.10). It is interesting to note that while the output of most agricultural sectors declines, it expands for meat products by $US 132m. Output in the manufacturing and services sector also increases ($US 483m). As expected, the greatest contraction in output occurs in milk products (or 9.3%, $US 394m), the most heavily supported sector. Changes in the volume of exports parallel those in domestic output, with the exception of exports of other agricultural and food products, which increase by $US 102m. As domestic production and exports contract, imports rise, but by small amounts. The largest percentage change in imports occurs in milk products (56.4%), and the largest volume change occurs in other agricultural and food products ($US 266m). Imports of manufactures and services fall by $US 136m, reflecting the expansion in domestic output. The removal of assistance on output and on exports, together with the removal of protection from imports, result in a decline in real producer surplus of $US 86m, an overall loss of $US 0.7m (Table 8.8).

Evaluation of second objective for Australia. In the context of the second objective of the study, the loss in producer surplus of $US 86m should be compared with the corresponding figures from the first two experiments. In these experiments it was concluded that under unilateral liberalization by the US, producer surplus in Australia would rise by $US 265m, and through removal of the CAP the corresponding gain would be $US 322m. Clearly, the gain from US and EU agricultural liberalization dominates the loss from unilateral liberalization by Australia. Hence, the Australian government's argument to the farm lobby that their income losses caused by the removal of assistance would be more than offset by the gains from trade liberalization appears to be correct.

Experiment 4: Liberalization by Canada

The shocks required to remove Canada's domestic agricultural policies and associated trade policies are given in the lower entries of Table 8.9. The

Table 8.10. ***Impact of Liberalizing Australian and Canadian Agricultural Policies ($US million; percentages in parentheses)***

	Output [qo]	Exports [qxw]	Imports [qim]
Wheat			
Australia (E3)	-51 (-2.6)	-45 (-3.8)	0 (6.7)
Canada (E4)	-1763 (-37.0)	-1711 (-39.9)	3 (83.7)
Other grains			
Australia (E3)	-12 (-1.8)	-9 (-2.7)	0 (10.2)
Canada (E4)	-654 (-21.4)	-374 (-49.5)	27 (23.7)
Wool			
Australia (E3)	-47 (-1.4)	-45 (-1.6)	3 (9.0)
Canada (E4)	-0 (-4.5)	-0 (-4.5)	-0 (-3.1)
Rice			
Australia (E3)	-4 (-1.3)	-1 (-1.4)	2 (10.1)
Canada (E4)	-1 (-1.3)	0 (8.9)	-4 (-4.5)
Meat products			
Australia (E3)	132 (1.7)	122 (4.7)	7 (19.6)
Canada (E4)	-1914 (-18.1)	-520 (-55.8)	1144 (109.6)
Milk products			
Australia (E3)	-394 (-9.3)	-277 (34.1)	81 (56.4)
Canada (E4)	-1277 (-16.2)	-258 (-92.0)	1437 (466.3)
O. Ag. and food prod.			
Australia (E3)	-233 (-0.8)	102 (2.9)	266 (13.6)
Canada (E4)	-5748 (-10.3)	-357 (-5.7)	2338 (30.7)
Manuf. and services			
Australia (E3)	483 (0.1)	270 (0.8)	-136 (-0.2)
Canada (E4)	9297 (0.9)	5156 (4.0)	-1766 (-1.3)

Source: GTAP simulation.

negative signs in the vector of liberalization shocks, *to*, indicate that outputs are subsidized. This domestic support varies across commodities, with wheat (14.4%) and meat products (18%) receiving the greatest degrees of support. Export support (the negative sign in *txs* indicating a subsidy) is largest for other grains (15.1%) and for milk products (44.1%), while the import shock (the negative sign in *tms*) on milk products (57.5%) is again substantially higher than for the other agricultural products. Wheat (22.4%) and other grains (12.7%), as well as meat products (18.0%) also receive protection from imports of not inconsequential amounts.

The results of unilateral Canadian liberalization, for a selection of variables, are presented in Table 8.10. The outputs of all agricultural sectors decline, with the largest percentage falls occurring in wheat (37%) and other grains (21.4%). There are also falls in the outputs of meat products (18.1%) and milk products (16.2%). In volume terms, the largest declines occur in other agricultural and food products ($US 5,748m), meat products ($US 1,914m), and wheat ($US 1,763m). The contraction in the agricultural sectors is accompanied by an expansion of $US 9,297m in the manufacturing and services sector. The falls in domestic output are matched (except for rice) by falls in exports, the most important of which occur in wheat ($US 1,711m) and meat products ($US 520m). There are attendant increases in imports of meat products ($US 1,144m), milk products ($US 1,437m), and other agricultural and food products ($US 2,338m). The effects of these adjustments in output are reflected in international markets through the price changes shown in Table 8.6. However, with the exception of the price of wheat (5.4%), the remaining price increases for agricultural products are inconsequential in comparison with those generated under E1 and E2.

The removal of Canadian for agricultural policies leads to a decline in producer surplus of $US 927m (Table 8.8). However, there is an overall national welfare gain of $US 814m from unilateral reform of Canadian farm and food policies.

Evaluation of the second objective for Canada. A part of the second objective in this chapter was to assess whether the Canadian government's political sensitivity to farm incomes was justified in the context of the trade negotiations and the stance of the Cairns Group under Australian leadership. In E1 and E2 the gains in producer surplus in the Canadian farm sector were $US 604m and $US 306m, respectively, whereas under unilateral Canadian liberalization, the loss is $US 927m. Hence, the government's sensitivity to welfare in the Canadian agricultural sector in the context of trade negotiations appears to have a sound foundation in political economy.

V Conclusions

This chapter had two principal objectives. The first was to determine whether the support the Cairns Group gave to the US in its sustained attack on the CAP was supported by economic analysis as reflected in the payoff to both

Australia and Canada. The results of the first two simulation experiments indicate that Australia would gain more from unilateral removal of the CAP than it would from unilateral removal of agricultural policies of the US; for Canada, more would be gained from a unilateral removal of US policies than from removal of the CAP. It must be stressed, however, that in the case of US liberalization, it has been assumed that existing land that is currently set aside is not brought back into production when price support policies are removed but that the land remains idle, for example, becoming part of a conservation reserve. In addition, it should be remembered that *except in the CAP liberalization experiment*, the EU's domestic markets for agricultural products have been totally insulated from international price changes in these experiments. With these caveats, it has been substantiated that the CAP is more of an impediment than is US agricultural policy to international agricultural trade and national welfare as perceived by Australia. This finding may explain both Australia's aggressive stance in relation to the CAP and also the Canadian government's more balanced approach as Canada gains more from US liberalization than from removal of the CAP.

The second objective was to investigate the stances adopted by the Australian and Canadian governments with respect to domestic political economy in their own farm sectors. For Australia, it was shown that losses to the farm sector from unilateral deregulation were smaller than the gains from successful unilateral international agricultural trade liberalization by the US and by the EU. In the case of Canada, the loss to the agricultural sector from the removal of government assistance exceeds the gains from unilateral agricultural trade liberalization by the US and the EU. Therefore, the respective positions adopted by each of these Cairns Group countries appear to have some justification in the political economy of domestic agricultural policy.

Historically, Australia has exhibited a sense of grievance at the conditions under which agricultural trade takes place and has perceived itself as being particularly vulnerable to the international political economy of agricultural policy. Until recently, these features have combined to produce a less than sensitive diplomatic touch in the area of international trade negotiations. Canada, on the other hand, has been constrained by its different agricultural structure with respect to provincial / federal relationships and by the importance of the US as a trading partner. This constraint has produced a more subtle style of diplomacy in trade negotiations as a balance has had to be struck between international obligations and domestic agricultural interests. Given such differences in the political forces operating on national governments in these two countries, it is remarkable that the Cairns Group remained an effective third force acting between the interests of the US and the EU in the Uruguay Round for as long as it did. Perhaps equally striking is the fact that the needs of the respective domestic political agendas are largely coincident with the economic conclusions derived from these simulations.

NOTES

1. The Cairns Group comprises the following countries: Argentina, Australia, Brazil, Canada, Chile, Colombia, Fiji, Hungary, Indonesia, Malaysia, New Zealand, Philippines, Thailand, and Uruguay. For a detailed description of the origins of the group, see Higgott (1988), and for an assessment of its role in the Uruguay Round until 1990, see Higgot and Cooper (1990).
2. An agenda moving coalition is one in which the principal aim is to ensure that the issues of particular interest to the member countries are properly dealt with in the negotiations (Hamilton and Whalley 1989).
3. "GATT has been ineffective in agriculture because it has tried to separate the international trade aspects of agriculture from the internal policies which lead to restrictions on international trade in agricultural products" [see reference to Dam, cited by Warley (1976), p. 339].
4. The "Red" book is the volume put out by the Bureau of Agricultural Economics (1985), and the "Gold" book is by Miller (1986).
5. Throughout this chapter, reference will be made to the EU, even although the change of name from European Community did not occur until November 1993.
6. After all, the US government claimed that it introduced the Export Enhancement Program (EEP) provisions only to counter subsidized exports of agricultural products by the EU and not to seek "unfair" advantage in international markets.
7. One specific commodity would have been of interest to Australia, particularly in its trade relations with the US and the EU, namely, sugar, but it is not present as a distinct commodity in the data base.
8. Volumes are obtained by running the program GTAPVOL, described in Chapter 6. This computes the following item: $0.01*qo(i, r)*VOM(i, r)$.
9. In the case of Japan, the effect is to transfer marginal resources from the manufacturing and services sector to certain of the agricultural sectors, for example, wheat and other grains (Table 8.5). If it is accepted that Japan has a comparative disadvantage in agriculture, then this inefficient use of resources is consistent with the loss of welfare of $US 3456m (Table 8.8).

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CHAPTER 9

Free trade in the Pacific Rim: On what basis?

Linda M. Young and Karen M. Huff

I Introduction and overview

The Pacific Rim contains many dynamic, export-oriented economies that have grown rapidly in recent years, shifting the world's economic center of gravity toward the east. The Asia Pacific Economic Cooperation (APEC) group was established in 1989, with 12 founding members. Its goal is to promote multilateral trade reform and to facilitate regional trade. Since its inception, APEC has expanded to its present membership of 18, including: the Association of South East Asian Nations (ASEAN) of Malaysia, Thailand, Indonesia, the Philippines, Singapore, and Brunei; the "three Chinas" – China, Hong Kong, and Taiwan; South Korea; Australia; New Zealand: Papua New Guinea; the US; Canada; Mexico; and Japan. Papua New Guinea and Mexico were admitted during the APEC summit in November of 1993 and Chile was admitted in 1994. Its member economies now account for almost 50% of the world's production and 40% of world trade (*Far Eastern Economic Review* 1993). In November 1994 the APEC members signed the Bogor Accord, which states that they will "adopt the long-term goal of free and open trade and investment" in the region. This will be accomplished by 2010 for industrialized countries and by 2020 for developing countries (*Wall Street Journal* 1994). The purpose of this chapter is to analyze the implications of such an agreement for trade and welfare in the region.

An initial reason given for the creation of a free trade zone in the Pacific is disillusionment over the effectiveness of the General Agreement on Tariffs and Trade (GATT) to sustain multilateral trade liberalization. It is unclear whether the long awaited conclusion of the Uruguay Round has done much to alleviate these concerns, in light of the limited measure of trade liberalization that it achieved. However, the increase in regionalism throughout the world, in particular, the trade diverting consequences of the European Union (EU) and North American Free Trade Agreement (NAFTA), has given impetus to the idea that the Pacific Rim should undertake action to create its own free trade area. In addition, the rise of trade friction between the US and countries in East Asia, particularly Japan, has resulted in suggestions of more effort to manage trade between countries bilaterally.

The idea of a Pacific Rim free trade area was first proposed by the Japanese economist Kyoshi Kojima in 1964, and has been discussed in various venues since then. One reason the area has not developed regional institutions earlier on is that when the Asian countries were ready for an economic takeoff, GATT had already succeeded in creating a relatively open trading regime (Eminent Persons Group 1993). Another reason is the diverse nature of the economies, cultures, and political systems, combined with the lack of a history of unifying institutions. For example, the countries in APEC have per capita incomes ranging from US $30,000 in Japan to less than US $1,000 in the People's Republic of China and Indonesia. These economies are quite likely to be affected in different ways by a free trade agreement. Moreover, the region contains not only two of the world's largest national economies but also some of the smallest. There is a perception that the smaller Pacific Rim countries would lose if such arrangements impinged on the growth of open trade.

Beyond the question of regional integration, there is the question of what form of economic integration to pursue. Some have argued that European-style integration is inappropriate for the Pacific region. For example, Drysdale (1988) argues that regional negotiations should not focus on discriminatory trade liberalization, but should be based on most favored nation (MFN) principles. He believes that the formation of a discriminatory free trade zone would damage the capacity for fluid changes in market share that has been crucial to the growth of these rapidly changing economies. Drysdale and Garnaut (1993) further argue that the countries in the Western Pacific have unilaterally liberalized trade, leading to an increase in trade throughout the region. They contrast this to GATT negotiations in which countries assume that liberalization is a concession, and in which they characterize trade expansion in the Western Pacific as a "prisoner's delight."

The feeling that multilateral trade liberalization is best for the region was also articulated by the prime minister of Australia, R. J. Hawke, who said at the first ministerial meeting of APEC in 1989, "A move towards some kind of a Pacific trading block . . . would be a foolish one, in that it would run counter to the region's absolutely compelling interest in the maintenance of a strong and open multilateral trading system. It is on such a system that the region's economic prosperity has been built, and continues to rely" (Hughes 1991). These arguments are similar in nature to those used in the debate over regionalism versus multilateralism in the global trading system.

This chapter focuses on the issue of multilateral versus preferential free trade in the Pacific Rim. We proceed as follows. First a brief discussion of the regional and commodity aggregation employed for the simulations is given. This is followed by an outline of the APEC trade liberalization scenarios to be examined. Next the results of the preferential trade liberalization scenario are discussed in detail and then the MFN scenarios are compared to it. The last section contains our conclusions.

II Aggregation strategy

The data base accompanying the GTAP model is well suited to examine the consequences of a free trade area in the Pacific Rim, since, with the exception of Brunei and Papua New Guinea, all the countries concerned are detailed in the data. The following 10-region aggregation was employed:

1. US, Canada, and Mexico (NAM)
2. Japan (JPN)
3. Australia and New Zealand (ANZ)
4. China and Hong Kong (CHN_HKG)
5. South Korea (SKOR)
6. Taiwan (TWN)
7. Malaysia and Singapore (MYS_SGP)
8. Thailand and the Philippines (THA_PHL)
9. Indonesia (IDN)
10. Rest of the World (ROW)

Individual countries were separated as much as possible in order to distinguish the welfare and trade effects of policy changes by country. However, in order to keep the analysis of a manageable size, in five cases two or more economies were combined. Owing to NAFTA an economic grouping of the US, Canada, and Mexico seems natural; in fact, the analyses in this chapter are conducted using a "post-NAFTA" data set. Combining China and Hong Kong is also sensible, since the trade data for the two regions are so intertwined. The other groupings are based on geographic considerations and/or the composition of trade. The ROW region is dominated by the EU. With the exception of Brunei, Chile, and Papua New Guinea, this ROW region faithfully aggregates those countries currently excluded from APEC.

The commodities are divided into three groups: food and agriculture, resources and manufacturing, and services. While this three-commodity grouping is admittedly aggregate, it begins to capture some of the differences in trade patterns in the APEC region under the various scenarios studied. Clearly, future analyses will need to investigate the consequences for specific subsectors within the food, resources and manufacturing, and services industries.

Table 9.1 reports the value of bilateral trade flows (imports) among the APEC members and with ROW. Seventy-two percent of APEC imports were from member countries in 1992, and that trade was valued at US $1,494 billion. Around 70% of trade by APEC members is in resources and manufacturing, with about 20% in services and 10% in food.

III Experimental design

All experiments were conducted with a multicountry, general equilibrium closure. The general equilibrium closure is appropriate for capturing the substitution in production and consumption that occurs between goods and the resulting changes in trade flows and values. Output levels, prices, and income are endogenous for all regions. Finally, the global bank's allocation of investment is fixed (*RORDELTA* = 0). Provided there is little change in the global composition of savings, this effectively fixes the trade balance for each country/region (see also Chapter 2).[1]

The experiments involve the complete removal of *ad valorem* import tariffs and tariff equivalents of bilateral nontariff barriers (NTBs) among the APEC regions. Export subsidies and taxes are not altered. This choice was made because the major export interventions present in the GTAP data base are those relating to the Multifibre Arrangement (MFA) and agricultural export subsidies. Since both of these areas have been addressed under the Uruguay Round agreement, they logically do not fall under the domain of an APEC free trade zone. It also seems unlikely that the US would participate in an agreement involving the liberalization of agricultural export subsidies without the involvement of the EU. For these reasons, the APEC liberalization scenarios analyzed involve import protection instruments only.

As mentioned in the previous section, the APEC trade liberalization experiments conducted in this chapter are based on a post-NAFTA data set. These data constitute an update of the standard GTAP data set that results from the removal of import tariffs and NTBs on the composite resources and manufacturing commodity within the North American region.[2] The results of this experiment are not discussed here and simply provide the starting point for each of the trade liberalization scenarios studied in this chapter. For example, the flows in Table 9.1 are estimated *post-NAFTA* imports at *post-NAFTA* market prices.

Table 9.2 shows the bilateral tariff (and tariff equivalent) rates for food (upper entry), and for resources and manufacturing (lower entry), for the 10 regions. (GTAP does not have protection data for the services sector.) Each row in this table refers to a particular source (exporter), while the columns

Table 9.1. ***Total Value of Post-NAFTA Imports at Importer's Market Prices (1992 U.S. $ million)***

	Destination									
SOURCE	NAM	JPN	ANZ	CH/HK	TWN	SKOR	MA/SG	TH/PH	IDN	ROW
NAM	363,197	111,187	17,821	27,435	21,593	31,311	19,687	11,218	5,712	316,844
JPN	140,422	0	11,793	44,165	26,429	26,773	26,701	20,988	8,002	159,846
ANZ	7,729	23,536	5,765	4,428	2,644	5,216	3,231	1,927	2,018	21,133
CH/HK	46,830	26,276	4,484	82,803	2,370	10,021	7,604	4,235	1,672	63,106
TWN	32,054	14,410	2,493	20,851	0	2,581	6,235	4,414	1,832	29,427
SKOR	24,627	17,792	2,101	10,409	2,620	0	5,799	3,717	2,631	39,085
MA/SG	26,823	16,929	4,035	11,069	6,278	5,637	21,432	9,295	3,000	39,420
TH/PH	15,480	13,228	967	3,956	958	2,339	4,777	517	590	18,891
IDN	6,056	15,138	1,257	3,356	1,524	3,008	3,964	825	0	9,857
ROW	263,993	128,009	20,800	47,349	14,106	34167	29,477	22,406	11,505	1,052,901
TOTAL IMPORTS	927,211	366,506	71,517	255,821	78,522	121,052	128,907	79,543	36,962	1,750,508

Table 9.2. ***Bilateral Tariff Rates for Food, and Resources and Manufacturing by Source and Destination (%)***

		Destination									
SOURCE		NAM	JPN	ANZ	CH/HK	TWN	SKOR	MA/SG	TH/PH	IDN	ROW
NAM	fd	12.40	128.75	5.52	7.54	144.67	156.33	0.84	35.19	41.55	21.22
	r&m	*0.00*	*2.94*	*17.58*	*9.10*	*7.54*	*16.02*	*2.20*	*27.52*	*10.73*	*8.52*
JPN	fd	5.38	n.a.	4.39	4.10	21.09	106.75	3.69	40.11	26.92	15.12
	r&m	*21.17*	*n.a.*	*21.17*	*13.58*	*5.84*	*18.19*	*3.72*	*33.83*	*14.34*	*16.08*
ANZ	fd	16.24	92.62	8.81	8.54	37.66	74.61	1.07	23.96	32.40	23.14
	r&m	*4.24*	*1.06*	*15.18*	*17.91*	*1.68*	*8.78*	*2.71*	*20.49*	*5.36*	*5.15*
CH/HK	fd	5.07	76.13	5.75	5.30	36.05	276.81	0.57	33.44	47.71	24.28
	r&m	*10.88*	*7.15*	*21.90*	*13.63*	*5.53*	*14.67*	*2.16*	*29.48*	*13.74*	*10.25*
TWN	fd	4.55	34.87	4.70	5.81	n.a.	86.49	0.68	56.30	40.98	44.68
	r&m	*10.74*	*5.95*	*17.17*	*13.55*	*n.a.*	*19.21*	*5.60*	*37.84*	*19.06*	*9.91*
SKOR	fd	5.24	28.37	4.66	1.91	47.16	n.a.	1.47	53.73	26.76	11.46
	r&m	*8.81*	*7.00*	*18.57*	*9.69*	*6.37*	*n.a.*	*3.37*	*30.27*	*17.96*	*11.79*
MA/SG	fd	6.80	22.77	6.62	14.86	30.49	170.12	0.63	37.11	21.71	16.12
	r&m	*6.11*	*2.55*	*19.82*	*6.58*	*5.68*	*14.03*	*4.35*	*28.93*	*11.28*	*9.27*
TH/PH	fd	5.57	39.26	5.02	10.77	54.44	187.92	8.27	26.44	12.94	29.33
	r&m	*8.56*	*4.67*	*13.69*	*4.73*	*4.07*	*16.22*	*2.21*	*37.18*	*15.18*	*9.32*
IDN	fd	6.41	23.01	6.34	12.22	40.66	180.48	0.80	52.28	n/a	23.05
	r&m	*9.60*	*3.16*	*10.08*	*15.03*	*3.19*	*9.09*	[illegible]	*25.80*	*n/a*	*9.92*
ROW	fd	10.0	51.54	8.51	9.89	45.77	110.55	1.71	47.20	32.04	23.42
	r&m	*8.07*	*3.08*	*16.23*	*14.51*	*6.15*	*11.84*	*2.55*	*26.82*	*12.89*	*8.75*

refer to destinations (importers). Several points stand out. First of all, looking at the diagonal elements of the table, notice that some regions have internal levels of import protection and for others this is not applicable (n.a.). The regions with internal trade barriers are always aggregate groupings of individual countries, such as North America and China and Hong Kong. The bilateral import protection represents an aggregated level of protection based on the levels of protection between the individual, disaggregate regions in the GTAP data base. The regions without entries on the diagonal are individual countries without internal trade barriers. Finally, the diagonal entry for North America for resources and manufactures is 0. This is because Table 9.2 corresponds to the *post-NAFTA* data base, which represents the starting point for experiments in this chapter.

The top entry in each row of Table 9.2 represents the import tariff equivalents for food and agriculture. Notice that the tariff equivalents on food imports into most of the East Asian markets are very high. For example, the average tariff equivalent on North American food exports to Japan (column headed "JPN," row labeled "NAM-fd") is almost 130%. The comparable figures for Taiwan and South Korea are 144% and 156%, respectively. Unfortunately, nontariff barriers facing agricultural imports were not available at the time of this study for Malaysia, Singapore, the Philippines, and Hong Kong (see Chapter 3). Consequently, the food protection estimates for these regions are understated.

Turning to the resources and manufacturing protection data, reported in the italicized entries in alternating rows of Table 9.2, we note that the average level of protection is lower than for food. These entries account for applied tariff rates, as well as antidumping duties in the case of the US, Canada, and the EU. The effect of these duties shows up in the bilateral rate of protection on imports from Japan to North America. The average applied tariff rates on merchandise imports into the US and Canada from Japan are only 7.6% and 5.2%, respectively. However, the antidumping duties are much higher – 31.4% in the case of US imports of machinery and equipment from Japan (see Chapter 3). Consequently, the combined bilateral protection rate on NAM imports from Japan is fairly high (21.17%).

The experimental design in this chapter *abstracts from* the changes proposed under the Uruguay Round of the GATT negotiations. At the time of this analysis, the outcome of that agreement was still unclear and it had not yet been adopted by all member countries. The associated trade reforms, when known, *could be* incorporated in the analysis, thereby permitting an assessment of the impact of additional (post-GATT) liberalization by the APEC countries. This would involve implementing a Uruguay Round trade liberalization scenario first, thereafter implementing the APEC trade reforms, using the updated data from the GATT scenario as the starting point. This is *not* done here.

Three experiments were performed:

- *Experiment 1: APEC Preferential Free Trade Area.* Import protection (both tariffs and NTBs) within the nine APEC regions were removed but maintained between the rest of the world and APEC. Although it is unlikely that an agreement would result in the complete removal of all import barriers, this experiment provides an upper bound for the benefits of APEC that can be captured by the model. (Export interventions are *not* altered.)
- *Experiment 2: APEC Trade Reform on a Most Favored Nation Basis (MFN); ROW does not reciprocate.* In this experiment the nine APEC regions remove import barriers for all regions including ROW; however, ROW does not reciprocate. As many leaders in APEC have argued against reforms on a preferential basis, this experiment provides an estimate of the consequences of extending these reforms on an MFN basis, without reciprocity from ROW.
- *Experiment 3: APEC Trade Reform on an MFN Basis; ROW reciprocates.* Now, import barriers are also removed on APEC–ROW trade. (However, they remain in place on ROW–ROW trade.) The purpose of this scenario is to provide an alternative benchmark for a multilateral trade liberalization experiment on an MFN basis. It seems unlikely that APEC members would agree to extend MFN status to ROW without some degree of reciprocity. Again export taxes and subsidies are not altered.

IV Results

The consequences of the preferential elimination of import barriers within APEC are examined first. These results are then compared to reform on an MFN basis, both with and without the reciprocity of ROW.

When a country participates in a free trade area, it may experience gains due to trade creation and either a gain or a loss due to trade diversion. The former has a positive effect on welfare, since the removal of tariffs within the region allows the country to allocate its resources more efficiently in production. The country is now able to import the goods that it formerly produced inefficiently behind its tariff wall from member regions that are more efficient producers (Caves and Jones 1981). Trade diversion in the context of a preferential APEC trading region might arise as follows. Prior to the removal of tariffs within APEC, Indonesia sourced more of its imports from the ROW region. This can be seen by looking at Table 9.1 across the row for ROW under the IDN column. Following a preferential APEC agreement, we find that the volume of merchandise Indonesia imported from ROW falls by

$2.4 billion. Other APEC member countries are now able to undercut ROW even if they were not as efficient as ROW in production. For example, South Korean exports to Indonesia rise by about $2.2 billion. Trade has been diverted from ROW to South Korea in this instance. If South Korea is, in fact, a less efficient producer, a welfare loss arises due to Indonesia switching the source of its imports away from the more efficient source. However, this loss may or may not be offset by the gain in welfare that results from tariff removal (Caves and Jones 1981). Both of these effects enter into the results of the preferential trade liberalization experiment and help to explain differences between this experiment and the MFN experiments.

Table 9.3 presents the effects of APEC trade liberalization on the volume of total trade including services.[3] The top figure in each row represents the change in the volume of total exports (valued at the exporter's market prices, in the initial equilibrium, measured in $US million), relative to the base data, under the preferential trade agreement. The lower figure in parentheses represents the *difference* between the volume changes under the preferential basis and the MFN basis. If the figure in parentheses is subtracted from the top figure, then the change in volume for the MFN experiment is obtained (see also footnote *b*, Table 9.3). This table shows that all APEC members gain export volume under both experiments (positive row totals) at the expense of ROW, which experiences a $37,563 million reduction in export volume. When the basis of trade liberalization changes from preferential treatment to MFN treatment, ROW does not lose nearly as much volume [–37,563 – (–32,358) = $–5,205 million], since under the latter scenario APEC countries also eliminate protection on ROW imports.

Recall from Table 9.2 that some of the APEC member countries had very high initial tariff equivalents, particularly on food. This indicates that the trade liberalization experiment should have the greatest impact in these regions. An examination of the volume of exports into South Korea (SKOR) shows that all other APEC members experience an increase in volume of exports to South Korea except for Australia and New Zealand (ANZ). Thus, it is not surprising that the *initial* bilateral tariff on ANZ imports was *relatively* low. For example, from Table 9.2, South Korea has import tariff equivalents of 74.61% and 8.78% on imports of food and of resource and manufactures, respectively, from ANZ versus tariff equivalents of 156.33% and 16.02% on North American imports of food and of resources and manufactures, respectively.

The ROW region loses export volume, relative to the base, in all APEC member regions except Japan and Malaysia and Singapore under the preferential trade liberalization scenario (across the row headed ROW). These two regions had the smallest tariffs on imports of ROW resources and manufactures (3.08 and 2.55, respectively); therefore, after formation of the APEC block, ROW is still competitive in those markets. When the experiment is conducted

Table 9.3. *Effect of Trade Reform on Volume[a] of Total Exports (1992 US million, evaluated at exporter market prices)*

From/To	NAM	JPN	ANZ	CH/HK	TWN	SKOR	MA/SG	TH/PH	IDN	ROW	TOTAL
NAM	-41658	77,008	6,179	6,083	15,268	13,295	1,880	4465	1971	-2196	82294
	(11,144)[b]	(3,417)	(1,901)	(2,083)	(859)	(2,394)	(-82)	(2021)	(670)	(-45173)	(-20767)
JPN	97,124	0	3,203	6,179	76	7,847	-2,165	7979	1058	-30816	90486
	(8,004)	(0)	(1,305)	(3,442)	(480)	(2,100)	(-110)	(3452)	(741)	(-17144)	(2268)
ANZ	1,956	6,051	1,427	2,544	-252	-309	256	185	317	-927	11247
	(267)	(-84)	(366)	(342)	(5)	(136)	(-94)	(263)	(163)	(-2906)	(-1541)
CH/HK	10,303	6,197	1,482	23,714	22	8,563	-556	1179	597	-8158	43341
	(103)	(-816)	(291)	(4,600)	(-32)	(484)	(-271)	(529)	(134)	(-9183)	(-4161)
TWN	6,719	809	450	5,315	0	755	826	4172	1017	-2985	17078
	(950)	(-108)	(223)	(1,632)	(0)	(121)	(-101)	(1131)	(227)	(-3932)	(141)
SKOR	10,169	7,425	1,154	3,745	1,113	0	1,484	3362	2180	1405	32036
	(1,003)	(-106)	(277)	(966)	(65)	(0)	(-75)	(966)	(408)	(-6082)	(-2577)
MA/SG	593	-142	1,294	178	549	1,368	1,633	2914	392	-4104	4675
	(1,089)	(101)	(481)	(816)	(190)	(421)	(137)	(1548)	(305)	(-4506)	(581)
TH/PH	8,175	3,050	428	1,145	308	1,584	2,100	730	230	2950	20700
	(326)	(-227)	(89)	(206)	(2)	(122)	(-211)	(138)	(61)	(-3469)	(-2963)
IDN	1,520	1,893	24	1,699	111	423	119	414	0	-316	5887
	(150)	(-315)	(91)	(274)	(6)	(150)	(-114)	(159)	(0)	(-1414)	(-1013)
ROW	-27,021	2,371	-5,016	-7,151	-519	-7,667	206	-9802	-2441	19478	-37563
	(-33,622)	(2,124)	(-5,747)	(-15,941)	(-1,077)	(-7,562)	(1,883)	(-11799)	(-3300)	(42682)	-(32358)

[a] The volume of exports corresponds to *one component* of the (*PM*) value flow [*VXMD(i,r,s)* = *PM(i,r)* * *QXS(i,r,s)*]. The change in the value of exports is driven by both the change in market price (*PM*) and the change in quantity component (*QXS*). The volume change refers to the change in the quantity component, which is valued at the *initial* exporter market prices. This provides the common, source-generic, metric.

[b] The terms in parentheses represent the difference between the preferential experiment and the MFN experiment without ROW reciprocity. Therefore, the preferential change in volume minus the difference equals the MFN change in volume (DIFF = PREF - MFN, therefore, MFN = PREF - DIFF) for measuring volume.

on an MFN basis, ROW is once again able to compete in most markets and increases export volume in all APEC regions with the exception of Japan, South Korea, and Malaysia and Singapore.

For the most part, trade among the APEC member regions is enhanced by a preferential agreement. For example, all the APEC members gain export volume into North America (down the column headed NAM) at the expense of NAFTA members and ROW, which both lose volume. Similar results hold for changes in export volume among the other APEC regions. When trade liberalization is conducted on an MFN basis, the members gain volume in the APEC region, but often to a lesser extent due to the increased involvement of ROW. For example, under the preferential agreement, North American exports to ANZ increase in volume by over \$6 billion, while under the MFN reforms they increase by just over \$4 billion. Adding up the export volumes from ROW to APEC regions (adding across the row headed ROW, but not including ROW), yields a *reduction* of over \$57 billion in trade volume under the preferential reforms versus an *increase* of roughly \$18 billion under the MFN reforms.

Under preferential trade reform, the volume of APEC exports into the ROW region falls, except from South Korea and Thailand and Philippines. ROW intraregional trade is enhanced. When MFN principles are used for trade reform, these results are mostly reversed. All APEC members except Japan gain export volume into ROW, and the volume of ROW intraregional trade declines. Specifically, in the first experiment there is an increase in intra-ROW trade volume of \$19,478 million, whereas in the second experiment there is a decline of \$19,478–\$42,682 = \$23,204 million.

Tables 9.4 and 9.5 detail changes in the terms of trade, real gross domestic output (GDP), and household utility for each region. Table 9.3 showed that the formation of the free trade area increased the volume of exports in all the member regions; however, this increase in exports is not necessarily accompanied by an increase in real GDP or utility. North America, Australia and New Zealand, Thailand and Philippines, and Indonesia all experience a decline in utility. As noted in Chapter 2, this change in terms of trade is often sensitive to the treatment of investment. As noted in an earlier footnote, Australia and New Zealand's terms-of-trade change is reversed when the investment is flexible. This can be explained by the deterioration these countries experience in their terms of trade. Notice that South Korea also experiences a deterioration in its terms of trade, but this effect is offset by the significant improvement in efficiency of domestic resource use, as reflected in the increased real GDP.

The terms of trade are defined as the ratio of the price received for tradeables (export price index) to the price paid for tradeables (import price index).[4] McDougall (1993) explains that in a model like GTAP, which differentiates

Table 9.4. ***Effect of Preferential Trade Reform on Terms of Trade, Real GDP and Utility*** **(*% change*)**

Region	Terms of Trade	GDP Quantity Index[a]	Household Utility
North America	-1.03	.07	-.11
Japan	4.08	.78	2.29
Australia and New Zealand	-.84	.18	-.07
China and Hong Kong	.96	.53	1.28
Taiwan	.81	1.78	2.40
South Korea	-2.01	4.32	3.16
Malaysia and Singapore	1.17	.38	2.42
Thailand and Philippines	-6.29	1.30	-3.05
Indonesia	-1.05	.46	-.17
ROW	-1.17	-.04	-.34

[a] The percentage change in the GDP quantity index equals the quantity change component of the percentage change in the value of GDP (*vgdp* = *pgdp* + *qgdp*). The change in the value of GDP is composed of a price change component (*pgdp*) and a quantity change component (*qgdp*). This quantity change component can be thought of as the change in real GDP.

products by country of origin, changes in the terms of trade can arise from changes in the relative prices of different source-specific varieties of the same commodity. A region's terms of trade will tend to improve if its exports of a commodity rise in price relative to the exports of other regions. A region's terms of trade will tend to worsen if it imports source-specific varieties that rise in price relative to other sources of the good. He proceeds to demonstrate how changes in the terms-of-trade index can be decomposed into three components: a component representing the contribution of changes in world prices, a component representing the contribution of changes in regional export prices, and a component representing the contribution of changes in regional import prices. An illustration of this type of decomposition for the changes in South Korea's terms of trade are presented and discussed in the appendix and the end of this chapter.

For the trade reform experiments conducted in this chapter, the negative changes in the terms of trade arise mainly due to the deterioration of regional export prices for resources and manufactures, particularly in North America, Australia and New Zealand, South Korea, Thailand and Philippines, Indonesia,

Table 9.5. *Effect of MFN Trade Reform on Terms of Trade, Real GDP, and Utility (% change)*

Region	Terms of Trade	GDP Quantity Index	Household Utility
North America	-2.15	.10	-.27
	(1.12)[a]	(-.03)	(.16)
Japan	2.60	.82	1.83
	(1.48)	(-0.04)	(.46)
Australia and New Zealand	-2.38	.33	-.38
	(1.54)	(-0.15)	(.31)
China and Hong Kong	-.43	.80	.60
	(1.39)	(-0.27)	(.68)
Taiwan	-.42	1.78	1.59
	(1.23)	0	(.81)
South Korea	-3.19	4.56	2.58
	(1.18)	(-.24)	(.58)
Malaysia and Singapore	.39	.29	1.02
	(.78)	(.09)	(1.40)
Thailand and Philippines	-7.79	2.46	-2.97
	(1.50)	(-1.16)	(-.08)
Indonesia	-2.84	.78	-.99
	(1.79)	(-.32)	(.82)
ROW	.65	0.02	.19
	(-1.82)	(-0.06)	(-.53)

[a] The terms in parentheses represent the difference between the preferential experiment and the MFN experiment without ROW reciprocity. Therefore, MFN percentage change plus the difference equals preferential percentage change as displayed in Table 9.4 (MFN + DIFF = PREF).

and ROW. World prices and composite regional import prices contribute relatively little to the terms-of-trade changes under the scenarios examined. Resources and manufactures make up the bulk of merchandise trade and, since the price received for exports declines relative to the price received for imports in these regions, a deterioration in terms of trade is experienced.

Although these results capture only a comparative static analysis of preferential trade reform, they suggest that this type of free trade area would promote growth in many member regions, but this could be at the expense of households in some cases. The North American region has experienced most of its gains through NAFTA, which is assumed to have been implemented already, prior to the APEC experiment. These results suggest that membership in the APEC region may not be beneficial for North America. Of course, this ignores the long-run effects of such an arrangement and the important political benefits of maintaining close ties within the Pacific Rim area. Although North America winds up losing under all three of the APEC simulations (see Table 9.6), it is important to keep in mind that these trade reform scenarios involve import protection liberalization only. Studies examining the impact of eliminating *export restraints*, like the one mentioned in Chapter 10 on reform of the Multifibre Arrangement (MFA), show significant gains accruing to the North American region.

When the APEC liberalization experiment is conducted on an MFN basis without the ROW region reciprocating, the welfare results obtained are qualitatively similar to those from the preferential experiment, except for ROW. Changes in terms-of-trade, real GDP, and utility under the MFN experiment are presented in Table 9.5. The figures in parentheses represent the differences between the results using a preferential basis and the MFN basis. Adding the difference to the percentage change for the MFN experiment yields the percentage change in the variable for the preferential experiment (Table 9.4). Notice now that the ROW region benefits from the APEC region liberalizing tariffs on its exports to the region. The benefits ROW experiences come at the expense of APEC member regions. North America, Australia and New Zealand, Thailand and Philippines, and Indonesia experience a decline in household utility that is larger in magnitude than under the preferential trade reforms. Although the other member regions still experience a gain from the liberalization, it is not as great as under the preferential scenario. This is supported by the fact that now more of the member regions experience a deterioration in their terms of trade, namely, North America, Australia and New Zealand, China and Hong Kong, Taiwan, South Korea, Thailand and Philippines, and Indonesia. Therefore, these comparative static simulations indicate that a trade reform package that extends MFN status to ROW, but does not require it to reciprocate, is not desirable for the APEC member countries.

Table 9.6 presents the welfare effects of the two previously discussed trade liberalization scenarios, as well as the third experiment, in which the ROW region reciprocates. It is interesting to note how well Japan fares under each of the scenarios. Under preferential trade reform Japan experiences a welfare gain of over \$71 billion, which represents about 77% of the \$93 billion in gross welfare gains. Japan's share of gross welfare gains drops to about 65% under MFN reform, without ROW reciprocating, but this increase bounces back to 76% when ROW does reciprocate in the reforms. The fact that Japan dominates the welfare gains in this analysis may be explained by its large initial share of APEC exports, which amounts to 20%. As well, Japan experiences a

Table 9.6. *Effect of Trade Liberalization on Welfare ($US million)*

Region	Preferential Reform 1	MFN Reform 2	Difference 1 — 2	MFN with ROW Reciprocating 3
North America	-6,625	-16,745	(10,120)	-2,260
Japan	71,564	57,339	(14,225)	93,955
Australia and New Zealand	-205	-1,134	(929)	738
China and Hong Kong	5,891	2,778	(3,113)	7,360
Taiwan	5,041	3,348	(1,693)	6,430
South Korea	8,424	6,894	(1,530)	10,967
Malaysia and Singapore	2,120	896	(1,224)	2,802
Thailand and Philippines	-4,577	-4,449	(-128)	-1,533
Indonesia	-202	-1,186	(984)	569
ROW	-31,668	17,592	(-49,260)	-47,195
TOTAL	49,763	65,333	(-15,570)	71,833

large increase in export volume under the reforms (see Table 9.3) and a noticeable improvement in terms of trade (Tables 9.4 and 9.5).

Some general observations on the effects of the different trade liberalization scenarios on welfare follow. When reform is conducted on a preferential basis, North America, Australia and New Zealand, Thailand and Philippines, Indonesia, and ROW all experience a reduction in welfare; the other APEC member regions gain. When the reforms are conducted using MFN principles, the results depend upon whether or not the ROW reciprocates in the reforms. When it does not reciprocate, ROW's welfare increases by over $17 billion; it falls by $47 billion when it does reciprocate. This loss in welfare is larger than the loss incurred under preferential reforms, but it is considerably reduced when the ROW region also liberalizes *intra*regional trade. When ROW does not reciprocate under the MFN reforms, all APEC members, with the exception of Thailand & Philippines, are worse off than under the preferential reforms. When ROW participates in the MFN reform experiment by cutting its import tariffs as well, the APEC members are better off than they are without its reciprocity. In fact, all the APEC members are even better off under the MFN reforms with ROW reciprocity than they are under the preferential liberalization scenario. These results seem to suggest that pursuing multilateral trade reforms is a wise strategy for the APEC member nations.

V Conclusions and qualifications

The results of the chapter highlight the importance of experimental design and the usefulness of GTAP in conducting an analysis of regional integration. Three different scenarios for APEC regional trade liberalization are examined and compared. The results show that the formation of an APEC trading block could result in both winners and losers in the group, as well as in ROW. The distribution of the gains and losses are affected by the assumptions that are made about the basis under which trade reform is conducted.

Conducting the APEC trade reform experiment on an MFN basis without the reciprocity of ROW delivers lower benefits for APEC members, and seems to support the arguments of Prime Minister Hawke in favor of *multilateral* trade liberalization involving ROW in trade negotiations. It has been argued, however, that regional reforms can lead to reform on a wider basis by providing impetus toward global trade reform. In that case, the analysis of this chapter suggests that APEC members would be better off to withhold tariff reductions on ROW imports until such time as they agree to reciprocity.

This chapter has demonstrated the suitability of the GTAP modeling framework for examining the impact of different types of trade agreements for the Pacific Rim, especially given its excellent coverage of the countries involved. However, some significant limitations must be noted. First, version 2 of the data base does not have complete coverage of agricultural protection for the countries involved in APEC. The protection data base also does not cover all the nontariff barriers that exist, although substantial progress has been made with the inclusion of the MFA and antidumping duties. This is a part of the data base that is constantly being improved as further information becomes available. Future analyses of alternative APEC agreements will benefit from these improvements.

Finally, note that the benefits of a preferential trading agreement cannot be fully captured by a perfectly competitive, static model. The benefits of increased competition, potential economies of scale, and the incentives for investment brought about by a preferential agreement will be fully realized only in the long run. These forces will likely increase incomes and with them, imports from ROW (McCalla 1992). While the GTAP model cannot capture all these dynamic effects from trade liberalization, it is a useful tool for generating comparative static results for a variety of trade reform scenarios, the comparison of which can provide direction in the path toward further trade reform.

Appendix: Decomposition of changes in terms of trade for South Korea

McDougall (1993) demonstrates that the change in the terms of trade can be decomposed into the contribution of world price indexes of all goods ($c1\_r$), the contribution of regional export prices ($c2\_r$), and the contribution of regional import prices ($c3\_r$).

$$c1\_r + c2\_r - c3\_r = tot.$$

Substituting in the values of the components for South Korea yields:

$$(.04) + (-1.81) - (.26) = -2.01.$$

As discussed in the chapter, this change in the terms of trade is dominated by the changes in the export prices for the region. This term ($c2\_r$) can in turn be decomposed:

$$c2\_r = sum(i \; \varepsilon \; TRAD\_COM, \; c2\_ir).$$

The term ($c2\_ir$) represents the contribution of the change in regional export price for good i to the change in terms-of-trade. Substituting in the values of the components for this equation yields:

$$(-.44) + (-1.51) + (.4) + (-.26) = -1.81.$$

The first term refers to changes in the price of Food exports for the region, the second term to changes in the export price of resources and manufactures for the region, the third term to the change in the export price of services for the region, and the last term to changes in the price of capital goods exports for the region. The change in the export price of resources and manufactures clearly dominates this calculation. This is reinforced by the fact that capital goods are constructed as a composite of the first three produced goods; thus, a portion of its price change reflects the change in the price of resources and manufactures.

NOTES

1. In a separate exercise, these experiments were all conducted using the flexible investment portfolio specification (*RORDELTA* = 1 and *RORFLEX* = 10). This dampens the terms-of-trade effects and actually reverses their sign for the ANZ region, which subsequently gains from preferential liberalization. Further analysis of the impact of APEC on investment patterns in the region is clearly warranted. The interested reader can pursue this issue by accessing the files associated with this chapter, following the instructions in Chapter 6.

2. Both the Canada–US Free Trade Agreement and NAFTA avoided full liberalization of food and agricultural trade. Rather, exceptions were granted, as well as more gradual implementation of agreed-upon cuts.
3. The volume of exports corresponds to *one component* of the (*PM*) value flow [$VXDM(i,r,s) = PM\ (i,r) * QXS(i,r,s)$]. The change in the value of exports is driven by both the change in market price (*PM*) and the change in quantity component (*QXS*). The volume change refers to the change in the quantity component, which is valued at the *initial* exporter market prices. This provides the common, source-generic, metric for measuring volume.
4. McDougall (1993) provides a methodology for decomposing changes in the terms of trade.

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CHAPTER 10

Evaluating the benefits of abolishing the MFA in the Uruguay Round package

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I Introduction and overview

The use of quantitative restrictions on textile imports from developing countries dates back to the 1930s (Keesing and Wolf 1980). At that time, the restrictions were mainly directed against the increasingly competitive Japanese cotton textile industry. After the Second World War, Japan's textile exports to the industrial countries spearheaded its export-led industrialization. However, the pressure for protection in industrial countries came not only from competition overseas, but perhaps more important, from the stagnant or even declining output and employment as a result of sluggish domestic demand (Keesing and Wolf 1980). Despite Japan's "voluntary" export restraints, a Short-Term Arrangement (STA) in cotton textile trade was reached in 1961 at the initiative of the US and under the auspices of the General Agreement on Tariffs and Trade (GATT). The conclusion of a Long-Term Arrangement (LTA) in 1962 established a system of quantitative protection against textile exports from developing countries (GATT 1984).

Despite the LTA, developing countries were able to expand their exports of textiles to industrial countries in the 1960s. Technological change strengthened the competitiveness of developing countries in textiles throughout this period. The emergence of synthetic fibers also enabled developing countries to find holes in industrial country restrictions, thereby increasing their market penetration. In addition, restrictions on Japanese products led to rapid growth of exports from other Asian countries, namely, Hong Kong, Taiwan, and Korea (Keesing and Wolf 1980). Under renewed pressure of competition from overseas, the US initiated the negotiations on the Multifibre Arrangement (MFA) in 1973. The MFA went into effect on January 1, 1974. It has been renewed several times since then.

The prominent feature of the MFA is its stipulation of the use of quantitative restrictions on textile exports from developing countries. Under the umbrella of the MFA, industrial and developing countries negotiate bilateral agreements on export quotas regulating textile trade. Thus, the MFA is discriminatory by country of origin. This is primarily achieved via voluntary export restraints (VERs). As a result, exporting countries capture the quota rents. The MFA stipulates 6% annual growth of exports from developing countries, but in practice the growth rates of bilateral quotas are frequently below the stipulated rate, and in some cases, even negative growth rates have been applied. Developing countries' exports are allowed to transfer a portion of an unfilled quota from one category to another ("swing"), use the unused quotas from the previous year ("carry-over") and borrow quotas from the following year ("carry-forward"). But limits are set on the ensuing flexibility.

The MFA restriction has become increasingly complex as the number of countries and commodities has been enlarged. Today, the MFA includes most major industrial and developing countries and covers products made of cotton, synthetic fibers, wool, silk and ramie, or their blends. In addition, the growth rates of quota volumes seem to be declining (Yang 1992). Global restrictions have also been applied by industrial countries in recent years. Under this arrangement, *all exports* are subject to quota when total exports from an exporting country reach a certain share of total imports in the country of destination.

In addition to the bilateral quotas, nondiscriminatory tariffs are frequently applied on imports of textiles and clothing, even when these products are subject to the MFA. The interaction between the tariffs and the MFA quotas introduces some complexities into the evaluation of the phase-out of the MFA proposed under the Uruguay Round agreement. The effects of quota removal depend upon second-best considerations, and theory alone is not sufficient to guide the selection of policies to improve the allocation of resources.

A path breaking feature of the Uruguay Round was an agreement to bring MFA-restricted goods under GATT disciplines. This liberalization process is being undertaken very gradually over a 10-year period, with MFA-restricted goods being returned to the normal GATT system (i.e., freed from export quotas) progressively over a 10-year period. Under the agreement, import tariffs are also being reduced, on both textiles and clothing and on a wide range of other goods. However, the rates of tariff reduction vary considerably between commodities, with considerably lower rates of tariff reduction on textiles than on most other goods.

The objective of this paper is to assess the effects of the removal of the MFA in the context of more general liberalization under the Uruguay Round agreement. To do this, we consider four separate experiments that shed some light on the nature of the welfare effects of liberalizing the MFA in the context of the Uruguay Round agreement:

1. Elimination of MFA quotas with non-MFA distortions in place
2. Reduction in tariffs on MFA goods alone
3. Non-MFA reforms
4. Implementation of the comprehensive Uruguay Round package.

To introduce the basic economic mechanisms at work, we first formulate the problem in simple partial equilibrium terms. Second, we briefly consider the nature of the liberalization undertaken under the Uruguay Round. Then, we consider the formulation of the problem in the Global Trade Analysis Project (GTAP) model. Finally, we discuss the nature of the experiments conducted. We report the results, then conclude our experiments.

II Consequences of liberalizing tariffs and MFA quotas

Normal tariffs are levied by the importing country, with the tariff revenue accruing to the importing country. Because of the precarious standing of the MFA in the international trading system, however, the developed country importers seeking to restrict exports from developing countries felt it necessary to "purchase" compliance by giving the exporters the right to control exports. Because export rights are scarce, they become valuable assets in those supplying countries that are internationally competitive suppliers. These assets are typically distributed free to exporting firms by governments on the basis of some criterion such as past export performance (Hamilton 1990).

If these export quota rights are freely traded, their value to exporters is equalized at the margin: exporters for whom their value is less than their market price sell them in the market; exporters for whom their value is initially more than the market price typically buy them. Even where quota transfers are illegal or restricted, typically there are arrangements for quota rental or for quota fulfillment through subcontracting so that it is realistic as a first approximation to assign a single quota premium across exporting firms in a single country. In this situation, the overall national quota can be thought of as imposing a tax on exporters equal to the purchase price of a unit of quota. For an exporter who has received a quota allocation, the cost of exporting is increased by the price for which the quota could have been sold, or the opportunity cost of holding the quota. For an exporter who does not initially have a unit of quota, the cost of exporting includes the purchase price of a unit of quota.

The assumptions we have made above treat the MFA more favorably as a policy instrument than it may deserve. There is evidence that the procedures used to allocate export quotas in developing countries may sometimes lead to substantial efficiency losses. There is also evidence that the developing country exporters do not receive the full benefits of the MFA quota rents. At least a part of the quota rents may be shared with the importing countries because of the market power of importing firms at the individual product level (Krishna, Erzan, and Tan 1994). In this analysis, we deal with the standard case in which the quotas restrict exports efficiently and the rents are transferred to the exporters.

When both a quota and a tariff are levied on the import of a good, and the import quota is binding, the quota level determines the volume of imports of the good. The domestic price of the good is, in turn, determined solely by domestic demand and the volume of the import quota. At a given world price, the difference between the domestic price in the restricted market and the world price consists of the tariff and the quota rent. The tariff rate is an exogenous policy variable; the tariff equivalent of the quota is endogenously determined by the level of the quota and the strength of domestic demand. Algebraically:

$$p_d = p_w(1+t)(1+q), \tag{10.1}$$

where p_d is the domestic price of the good; p_w is the world price of the good; t is the *ad valorem* tariff rate; and q is the tariff rate that would be equivalent in its restrictive effect to the export quota.

To aid understanding, we first consider the case in which a single exporting region faces two sources of demand: the restricting market, and the rest of the world (ROW). To illustrate this, we draw an extended version of a diagram presented in Martin and Suphachalasai (1990, figure 3.3). The major extension in this diagram is the incorporation of the effects of a tariff on imports into the quota-restricted market. In Figure 10.1, total import demand consists of two components: $Z_p^1(t)$ is the net demand for imports by the developed regions in the presence of an initial tariff, t, on imports into this market; and Z_p^2 is the net demand for imports by ROW. The resulting total import demand is given as $ED(t)$. The supply of exports from the developing countries is given as $-Z_p^0$.

Without the MFA quota, the market clears at world price, $p_e(t)$ in Figure 10.1. With imposition of an MFA export quota, the total import demand becomes the kinked curve *abc*. In the presence of both the tariff and the quota, the world market clears at a lower world price, p_w, which is the price received by developing country exporters for their exports to the non-MFA market. The price received by developing country exporters for their exports to the MFA-restricted market is p $(=p_w(1+q))$; the price paid by consumers within the restricted market is p_c $(=p_w(1+t)(1+q))$. The quota regime results in rents of $(p-p_w)Q^*$ being transferred from the restricting importer to the exporting region where Q^* equals the quantity of exports into the MFA-restricted market.

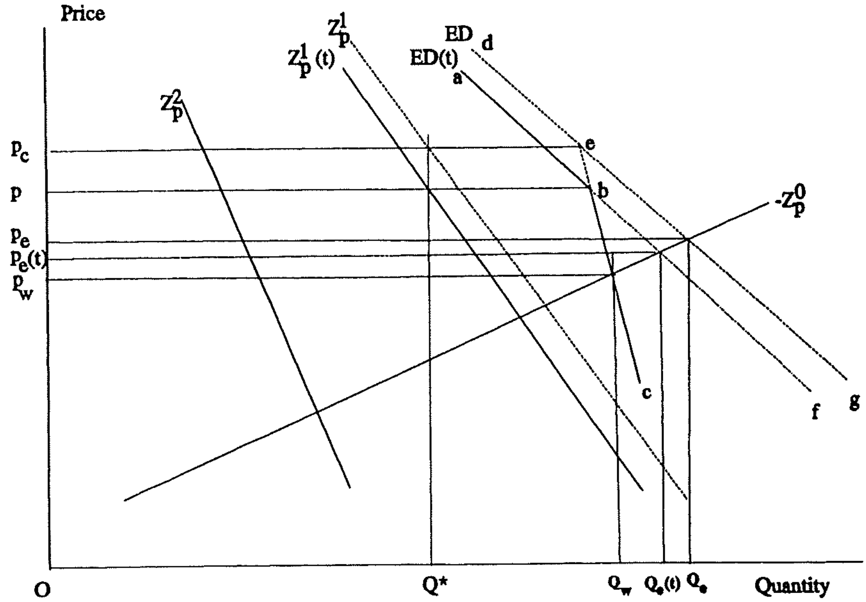

Figure 10.1. Effects of a VER and a tariff.

Starting from the distorted equilibrium depicted in Figure 10.1, the effects of removing the tariff and the quota can be considered in turn. Removal of the tariff shifts the import demand curve for the restricted market up to Z_p^1 and is associated with a rise in the price received by MFA exporters for these exports to p_c. The total import demand curve, $ED(t)$, shifts upward only to the left of the kink point b, that is, in situations when the quota was not previously binding. The new total import demand curve is thus the kinked curve, *dec*. Assuming a binding quota, the world price, p_w, is unaffected by this change, as are the volume of imports and exports in all markets. This illustrates the fact that *the tariff in this case is purely a rent shifting tariff*: its sole effect is to determine the allocation of the difference between the world price and the price in the restricted market between quota rents to exporters, and tariff revenues to importers.

The effects of abolishing the MFA quota are considerably more complex than those of removing the tariff on the quota-constrained goods. With the tariff in place, the total import demand curve becomes *abf*, and without the tariff it is the curve *deg*. The quantity of exports to both importing markets rises from Q_w to $Q_e(t)$ while the world market price rises to $p_e(t)$ in the presence of the tariff. In the absence of the tariff, total imports increase to Q_e and the world market price is p_e. As a consequence, the exporters are able to expand their output, reaping an efficiency gain in the process, as emphasized by de Melo and Winters (1993). With a tariff, the price received for products sold in the restricted market, however, declines from p to $p_e(t)$, implying a loss of quota rents on the goods sold to the restricted market. The overall welfare effects of the change depend upon whether the loss of rents on products sold in the restricted market is outweighed by the increase in prices received from unrestricted markets and the efficiency gains associated with increasing output.

Whether an exporter will gain or lose from quota liberalization clearly depends upon the magnitude of the price changes in the restricted and unrestricted markets, and upon the relative importance of each market for that exporter. The magnitude of the price effects, in turn, depends upon the price responsiveness of the restricted and the unrestricted markets. In the appendix to this chapter, we use a simple theoretical model, consistent with the diagram, to show that the welfare effects of liberalization depend in a relatively straightforward way upon the share of its exports sold to quota-restricted markets, and on the relative magnitude of the price decline in the restricted market and the price increase in the unrestricted market.

Where tariffs apply to goods other than the restricted good, government revenue changes in markets other than the restricted one must also be considered. Liberalization of textile and clothing quotas will lower the domestic prices of textiles and clothing and therefore can be expected to reduce demand for imports of goods that are close domestic substitutes. The resulting changes in tariff revenue must be considered when evaluating the welfare effects of liberalization (Anderson and Martin 1993). Thus, the larger the reductions in tariffs on imports of goods that are substitutes for textiles and clothing, the more likely it is that removal of MFA quotas will be welfare-improving.

In addition to the distortions facing developing country exporters, other important influences on whether they will gain or lose from removal of the MFA quotas are the shares of their products sold in the MFA markets, and the elasticities of demand they face in each market. If a supplier has a low elasticity of demand in the restricted market (and hence achieves large price gains per unit of sales forgone), then it is more likely to lose from the MFA removal. An exporter that has a large quota relative to its supply potential, and hence sells a higher proportion of its exports in the restricted markets, is also more likely to lose from the abolition. Given the structure of the GTAP model, export demand elasticities across markets are quite similar. Thus, the share of exports to the restricted market is most relevant in making these assessments. Table 10.1 identifies the commodities/regions used in our aggregation, and Table 10.2 reports the restricted export shares. For textiles, the newly industrializd economies (NIEs), Association of South East Asian Nations (ASEAN), and China all send only a small share of their exports to the restricted markets. South Asia and Latin America have a higher orientation to these markets, while the ROW region has the highest degree of orientation

Table 10.1. *Regional and Commodity Aggregation*

Regional Aggregation	Commodity Aggregation
1. Australia Australia New Zealand	**1. Agriculture** Paddy rice Wheat Nongrain crops Wool Other livestock Forestry Fisheries Processed rice
2. North America US Canada	
3. EU	
4. Japan	**2. Mining** Coal Oil Gas Other minerals Nonmetallic minerals
5. NIEs Hong Kong Republic of Korea Taiwan	
6. ASEAN Indonesia Malaysia Philippines Singapore Thailand	**3. Processed food** Meat products Milk products Other food products Beverages & tobacco
7. China	**4. Textiles**
8. South Asia	**5. Clothing** Wearing apparel
9. Latin America Argentina Brazil Mexico Rest of Latin America	**6. Iron and steel** Primary ferrous metals
	7. Machinery and equipment
10. ROW Sub-Saharan Africa Middle East & North Africa Economies of Transition ROW	**8. Transport equipment** Transport industries
	9. Other manufactures Leather, etc. Lumber Pulp paper, etc. Petroleum and coal Chemicals Rubbers and plastics Nonmetallic minerals Nonferrous metals Fabricated metal products Other manufacturing
	10. Nontradeable services Construction Trade and transport Electricity, water, and gas Other serives (private) Other services (government) Ownership of dwellings

to the MFA-restricted markets. However, ROW includes some developed countries whose access is not restricted by the MFA, so this region effectively faces limited restrictions. (This is reflected in its relatively low average export tax equivalent.)

Table 10.2. ***Export Shares and Tax Equivalents of MFA Quotas (% of fob prices)***

	Textiles			Clothing		
	Share Restricted	Tax Equivalents		Share Restricted	Tax Equivalents	
Exporter		North America	EU		North America	EU
NIEs	0.11	8.8	10.3	0.71	18.9	16.3
ASEAN	0.23	12.0	16.0	0.55	36.5	38.2
China	0.16	18.9	27.4	0.26	40.4	36.1
South Asia	0.39	19.0	27.4	0.78	40.4	36.1
Latin America	0.48	9.6	14.2	0.87	20.2	17.6
ROW	0.66	4.6	6.2	0.86	8.6	8.7

Source: GTAP data base.

Table 10.3. *Tariff Reductions in Industrial Countries Agreed Under the Uruguay Round (%)*

Rate of tariff reductions imported from:	All	Developing	Developed
Agricultural products	36.0		
Mining products	34.4	35.0	33.7
Processed food	21.3	22.4	19.5
Textiles and clothing	20.0	21.2	18.9
Iron and steel	62.2	66.7	60.6
Machinery and equipment	48.8	48.6	48.8
Transport equipment	21.6	18.4	21.8
Other manufactures	41.9	39.7	42.5

Source: Computed from table 11, GATT (1993).

In the clothing market, the developing country exporters tend to rely much more heavily on the MFA importing markets than is the case in textiles. There are very large differences in the extent of this reliance, however, with China exporting a much smaller share to MFA markets than the other suppliers. ASEAN is also relatively more diversified, with only 55% of its exports going to MFA importing markets. Latin America is the most dependent upon the MFA importing markets, with 87% of its exports going to these two markets.

III Liberalization under the Uruguay Round

In this analysis, we focus on the gains in market access provided for under the Uruguay Round agreement, rather than the systemic reforms to the trading system, which may well be of even greater importance. Specific estimates of the gains in market access under the round were not available at the time of writing. The broad estimates presented in Table 10.3 are generally similar to those used in earlier studies (e.g., Goldin, Knudsen, and van der Mensbrugghe 1993) and provide a broad estimate of the intended nature of the liberalization. We draw upon more recent GATT (1994) estimates of tariff reductions of 10% and 15% for textiles and clothing and transport equipment, respectively, in North America. For developing countries, we follow Brandão and Martin (1993) in assuming that agricultural trade distortions will be reduced by two-thirds of the developed country reductions. In addition, we assume here, for want of better information, that developing countries reduce their industrial sector protection by two-thirds of the reduction achieved by industrialized countries.

Although the phase-out of the MFA will occur gradually, our framework is really suitable for analyzing only comparative static effects. Because we are primarily concerned with understanding the consequences of liberalization in the presence of multiple distortions using a comprehensive general equilibrium model, rather than determining the actual impact of the Uruguay Round, we first evaluate the effects of an immediate phase-out of the arrangement. Given the rapid changes occurring in comparative advantage in this industry, and the likely tendency for the arrangement to become more restrictive over time (Yang 1994b), the effects of MFA liberalization seem more likely to be favorable for developing countries at the end of the phase-out period.

The effects of liberalization depend heavily upon the magnitude of the initial distortions. We draw on the GTAP data base for estimates of the magnitude of these distortions (see Chapter 3). All industrialized regions (except Australasia) and the NIEs have sizeable production subsidies for agriculture, with the European Union (EU) having the highest level of support. Only North America and the EU maintain sizeable export subsidies for agricultural exports. Tariffs or their equivalents on agricultural commodities are very high in the EU, Japan, and the NIEs. They are also quite high in ASEAN and China. Among manufactured goods, only processed food and textiles and clothing are subject to relatively high tariffs in industrial countries. The NIEs have the lowest tariffs on manufactured goods among developing countries, and China seems to have the highest.

The export tax equivalents of the MFA on textiles are reported in the first group of columns in Table 10.2. They are higher in the EU than in North America; for clothing (second group of columns) North America is generally more restrictive. ASEAN, China, and South Asia are the most severely restricted textile and clothing exporters. These regions were not major exporters of textiles and clothing when the MFA was established, and their exports of goods under the MFA are lower, relative to their total exports, than is the case in the NIEs.

For simplicity, we assume that all textile and clothing categories are restricted by the MFA, although we know that not all textile and clothing categories are covered by binding MFA import quotas [for estimates of these coverage ratios see Hamilton (1990)]. Ideally, we would divide total imports of textiles and clothing into two groups: those restricted by the MFA, and those unrestricted. However, this would involve introducing additional commodities, and hence introducing a fundamental distinction between commodities and industries that is not present in the current data base. Further, the distinction is probably less important than it might appear, since many of the products not explicitly restricted by the MFA are essentially under its shadow, and would come under its restrictions if their export levels increased.

IV Experimental design

Experiment 1 (E1)

Our first experiment consists of the elimination of MFA quotas in the presence of the pre–Uruguay Round tariffs. Because the quotas are being fully liberalized, it is appropriate to impose the shock by specifying the quotas as though they were implemented by using export taxes of equivalent restrictiveness (see Table 10.4 for a summary of the four experiments). The MFA phase-out is simply implemented by imposing shocks that will reduce the export tax equivalents (*txs*) of the MFA quotas to zero. Exogenous variables in this closure include population, the numeraire price of savings, all technological change shifters, all slack variables except the Walrasian slack variable, all policy variables, and all endowments.

Experiment 2 (E2)

In our second experiment the reduction of tariffs on textiles and clothing alone is imposed directly by reducing these tariffs (*tms*) by the amount (an average of 21% for industrial countries and 14% for developing countries) estimated to have been agreed under the Uruguay Round. At the same time, the export tax equivalents of the MFA for textiles and clothing (*txs*) are endogenized, and the corresponding exports (*qxs*) from developing countries are fixed. The results of this experiment provide something of a check on the model. We know that the welfare gains to developing countries of this experiment should be almost equal to the change in their export tax revenues, plus any welfare impact of their own tariff reductions in textiles and clothing. This is because there are no quantity adjustments occurring, and hence no price changes. The only effect of the tariff reduction is to increase the quota rents accruing on exports of these goods.

Experiment 3 (E3)

Similarly, in experiment 3, the export tax equivalents for MFA quotas on textiles and clothing are endogenized and the corresponding exports from developing countries are modeled as being determined by exogenous quotas. The shocks now, however, cover all non-MFA reforms. Thus, policy variables subject to shocks include import tariffs for all commodities (see Table 10.3) and agricultural output subsidies (20% cut) and export subsidies (36% cut). The effect of liberalizing all non-MFA distortions depends upon the usual considerations such as efficiency gains, terms-of-trade gains, and induced changes in tariff and other tax revenues (second-best effects). Since trade liberalization is a positive sum game, the overall gains will be positive, although there is no guarantee that some regions will not lose.

One second-best consideration likely to be important in experiment 3 is the possibility of changes in the export tax equivalent on textiles and clothing when other goods are liberalized. Assuming other goods are substitutes for textiles and clothing, reductions in other tariffs will reduce the import demand for textiles and apparel, and hence reduce the quota rents accruing to exporters.

Table 10.5. ***Impact of Pre-Uruguay Round MFA Removal (E1) and the full Uruguay Round (E4) on the Textile and Clothing Sector* (%)**

	Activity Level				Exports			
	Textiles		Clothing		Textiles		Clothing	
	E1	E4	E1	E4	E1	E4	E1	E4
Australasia	0.5	-3.1	-0.3	-3.6	4.7	1.1	-25.5	-10.6
North America	-11.8	-12.9	-41.6	-44.6	-5.8	-4.0	-13.8	-7.4
EU	-4.2	-3.9	-33.0	-34.1	3.2	7.6	6.6	15.2
Japan	1.1	2.1	0.3	-0.8	6.2	15.5	-27.2	-23.4
NIEs	7.0	15.5	-16.2	-10.4	16.9	29.0	-27.4	-19.2
ASEAN	53.4	55.2	129.2	143.2	22.3	25.6	252.8	279.6
China	15.8	13.4	73.9	81.9	7.9	10.3	130.0	144.0
South Asia	17.3	16.8	91.7	91.1	24.6	26.0	253.7	252.5
Latin America	-0.5	-1.7	-3.7	-5.0	12.0	12.7	-23.0	-23.2
ROW	-6.1	-7.5	-15.3	-16.3	-5.3	-3.4	-57.8	-56.3
World	1.6	1.8	-2.7	-2.3	8.5	14.	53.6	62.9

Table 10.6. ***Welfare Effects of MFA Removal Vs. non-MFA Reforms (in both the Pre—Uruguay Round Setting and the context of the Uruguay Round (UR): (in 1992 $US million)***

	Equivalent Variation (EV) in $US millions						
	E1 (pre-UR MFA REFORM)	E2 (UR tariff cuts on TXL & CLG)	E2 Δ rent premium	E3 (non-MFA UR)	E3 Δ rent premium	E4 (complete UR With MFA Reform)	Differences E4—E3
Australia	157	32		646		857 [0.3]	211
North America	16,442	-768		1,306		19,087 [0.3]	17,781
EU	12,144	-1,023		10,620		24,083 [0.4]	13,463
Japan	-1,615	-95		24,697		23,012 [0.7]	-1,685
NIEs	-4,52	1,048	478	4,488	559	-108 [0.0]	-4,595
ASEAN	3,523	369	269	364	350	4,315 [1.2]	3,951
China	5,184	790	299	649	283	6,204 [1.9]	5,555
South Asia	2,128	270	203	12	146	2,020 [0.7]	2,008
Latin America	-1,602	183	150	1,566	86	308 [0.0]	-1,259
ROW	-4,397	645	630	1,161	756	-4,655 [0.2]	-5,816
World	27,437	1,404	2,029	46,523	2,180	75,124	28,600

Note: Numbers in brackets are percentages of 1992 income.

Table 10.7. ***Terms-of-Trade Effects, by Experiment (% change)***

	Terms of Trade			
	E1	E2	E3	E4
Australasia	0.19	-0.05	-0.01	0.2
North America	1.16	-0.10	-0.05	1.2
EU	0.62	-0.08	-0.52	0.2
Japan	-0.14	-0.02	0.84	0.7
NIEs	-1.05	0.23	0.08	-1.1
ASEAN	-0.94	0.08	-0.17	-1.2
China	-1.41	0.08	-0.49	-2.0
South Asia	-2.00	0.34	0.42	-2.0
Latin America	-0.54	0.03	0.22	-0.3
ROW	-0.4	0.06	-0.17	-0.6

$27 billion, similar to the $22 billion estimated by Trela and Whalley (1990) but much greater than the estimate of Yang (1994a), which is on the order of $6.5 billion (in 1986 prices). In terms of the benefits to developing countries, however, the results of the three studies are quite close. In fact, this study estimates that developing countries (excluding ROW) benefit less than shown in the Trela–Whalley and Yang studies.

Apart from the difference in price bases, the difference between this and Yang's estimate largely results from the overall higher MFA export tax equivalent applied in this model. It seems plausible that the estimate of this study captures the upper bound of the MFA effect and that of Yang the lower bound. As pointed out earlier, we have assumed that all textile and clothing exports from MFA-restricted developing countries are subject to constraint. If some textiles and clothing are not affected or affected only to a lesser degree by the MFA, our results will tend to overestimate the overall impact of the MFA. This is particularly true if there is a high a proportion of unrestricted products in a country's exports.

In both the Yang and Trela–Whalley studies, virtually every exporting country benefits from abolition of the MFA. In this study, however, although the more restricted and efficient exporters – namely, ASEAN, China, and South Asia – gain substantially, the exporters who face less stringent restrictions, either because of the size of their current quotas or because of their cost structures, lose from quota abolition. In the model simulation, this group includes the NIEs and Latin America (and ROW, to the extent that it includes some developing countries). This seems to result not only from the displacement of their exports by ASEAN, China, and South Asia, but also from the deterioration of their terms of trade and the loss of quota rents.

The terms of trade for the exporters with lower export shares in restricted markets also decline as a result of losing quota rents. However, the efficiency gains to these exporters are sufficient to outweigh these terms-of-trade losses, and lead to a welfare improvement for them. This confirms a well-established prediction that many developing countries will gain from the abolition of the MFA despite their loss of quota rents.

Our welfare estimates for North America and the EU lead us to two of the most robust conclusions from research on trade liberalization: (1) countries that impose trade restrictions tend to do more harm to themselves than to others, and (2) trade liberalization generally benefits those undertaking liberalization much more than those hoping to gain from the liberalization efforts of others. As a result of MFA removal, consumer prices in the two markets decline, as they no longer have to pay quota premia to exporting countries. This is reflected in the considerable improvement in the terms of trade for North America and the EU. Producers in MFA importing countries lose, but their losses are much smaller than the gains to consumers. One final factor contributing to the welfare gain of MFA importing countries is the increased tariff revenues. Despite the fact that tariff rates are not affected by the MFA removal, increases in import volume increase tariff collections.

Japan's loss from MFA abolition is also to be expected. The removal of the MFA raises world prices for textiles and clothing. As a net importer of these products, Japan's terms of trade deteriorate. The rises in world prices in non-MFA markets help domestic production, but Japan's clothing exports to North America and the EU are substantially reduced. As a result, both textile and clothing production increase only marginally. Overall, the terms-of-trade effect seems to have dominated other effects.

Regardless of who gains or loses from the demise of the MFA, the mechanism that determines the welfare impact of MFA removal on individual countries seems clear. Without simultaneous liberalization in other areas of the world economy, the abolition of the MFA will largely benefit the exporting countries that are subject to most severe restrictions and the MFA importing countries. Other countries are likely to lose as a result of deterioration in their terms of trade or loss of quota rents, or both.

Implications of non-MFA reforms

As pointed out earlier, second-best effects are an important factor in the context of the Uruguay Round reform. In particular, non-MFA reforms can also have important implications for the stringency of the MFA and quota rent transfers during the course of trade liberalization. Unlike tariffs, which provide constant rates of protection on domestic industries, MFA quotas provide variable protection because the associated quota rents are endogenous, while export volumes are exogenously fixed. In a general equilibrium context, when agricultural liberalization and tariff reductions occur before MFA quotas are completely abolished, the restrictiveness of the quotas changes and so do rent transfers. Given that the phase-out of MFA quotas is heavily loaded in the last few years of the 10-year transition period, and that non-MFA reforms are likely to be completed sooner, change in the restrictiveness of the MFA and hence quota rent transfers in the transition period is a relevant policy issue.

Two experiments were conducted to shed some light on these second-best considerations. In the first experiment, E2, tariffs on textiles and clothing are reduced by 21% in developed countries (15% in North America) and 14% in developing countries, leaving all other distortions (including the MFA) in place. The next experiment, E3, extends trade liberalization to include all non-MFA reforms, including tariff cuts on textiles and clothing. It should be noted that in both experiments, although textile and clothing exports from MFA exporting countries to MFA importing countries are fixed, the export tax equivalents on them are allowed to change, reflecting the endogenous nature of the MFA-imposed export taxes.

The welfare and terms-of-trade effects of the non-MFA reforms are shown in Tables 10.6 and 10.7, respectively. In Table 10.6 there are also entries referring to the changes in quota premiums as a result of the reforms. Tariff cuts on textiles and clothing in industrial countries lead to increases in import demand that raise the per unit quota rents accruing to exporting countries and increase the volume of exports on which rents are received. Because no import quantity adjustments occur, consumers in industrialized countries fail to benefit from the tariff reductions, as can be seen from the deterioration of their terms of trade due to their strengthened demand for imports. As a result, developing countries gain and industrialized countries lose.

It is worth noting that gains to developing countries from the tariff cuts account for a major or even dominant portion of their total gains and that the total gain to developing countries equals nearly 90% of the total welfare loss to North America and the EU. Had the same extent of protection on textiles and clothing been achieved by tariffs alone instead of a combination of the MFA and tariffs, MFA importing countries would have been likely to benefit from tariff reductions on textiles and clothing. This experiment thus highlights the point that the MFA is an inferior policy option to protect a domestic industry in comparison to tariffs. Politically, it has mitigated the resistance to the discriminatory restrictions by developing countries.

This experiment points to the vital role that the high tariffs on textiles and clothing play in the transfer of MFA quota rents from industrialized countries to developing countries. In the presence of the MFA, the tariffs serve as an instrument to extract quota rents that would otherwise have accrued to developing country exporters. In the extreme case, the entire rents generated by the MFA can be obtained by industrial countries if tariffs are set at such levels as to eliminate any quota premium generated by the MFA. It should be noted, however, that the tariffs that extract maximum quota rents are not necessarily optimal tariffs. Thus, industrialized countries might still lose from the MFA even if they were able to capture the full quota rents.

In contrast with the case of MFA removal, tariff reductions on textiles and clothing will benefit all MFA exporting countries, not only the more efficient ones, as is the case when the MFA is removed. If anything, the more established exporting countries, such as the NIEs, may benefit more from the tariff reductions as they tend to have larger market shares than their price competitiveness would dictate in MFA importing countries. The quota rents accruing to them can therefore be disproportionately large.

When trade liberalization extends to non-MFA commodities (E3), all countries benefit. Japan is the largest beneficiary from the extended trade liberalization. Despite a considerable deterioration of its terms of trade, the EU benefits nearly three times as much as North America. In both North America and the EU, however, increases in quota rent transfers to developing countries are more than offset by the efficiency gains from tariff reductions.

The overall gains for developing countries from non-MFA reforms disguise the net contribution of the extended component of trade liberalization (i.e., E3-E2). While the NIEs, and Latin America benefit substantially from such an extension, China, and South Asia in fact lose from it. ASEAN barely gains. For these regions, increased rent transfers from industrial countries remain important to their total gains from non-MFA reforms. The losses to China and South Asia result from the adverse effect of the extended trade liberalization on the terms of trade for these regions and, to a lesser extent, from losses in MFA rent income (due to a decrease in export volume).

The deterioration in the terms of trade (Table 10.7) for the EU and China seem to be quite drastic, particularly in the case of China. Examination of the composite commodity price changes for exports leaving, and imports entering, each region (not shown here) reveals that for China the deterioration of terms of trade occurs most markedly in agricultural products, for which both ASEAN and China are substantial net importers. In addition, tariff reductions in the highly protected industrial sectors in China and, to a lesser extent, in ASEAN lead to an import surge in these sectors. Furthermore, tariff reductions substantially lower the costs for the exporting sector and boost manufactured exports. Under the regional product differentiation (Armington) assumptions in the model, this type of trade expansion translates into considerable declines in export prices. The declines are most pronounced for machinery and equipment, one of the largest export items for ASEAN and China.

Three factors may explain the deterioration in the terms of trade for the EU. In comparison to North America, the EU has higher tariffs on manufacturing imports, except for textiles and clothing. The EU's tariffs on manufactures are also considerably higher than those of Japan, except for clothing. In addition, agricultural reform shifts considerable resources from agriculture to manufacturing. Both of these factors boost manufactured exports in the EU more than in North America and Japan, and hence lead to greater suppression of its export prices. The third factor contributing to the larger decline in the EU's export prices derives from its export destinations. In both proportional and level terms, the EU exports less than North America and Japan to the liberalizing NIEs, ASEAN, and China, where tariff reductions have generated large demand for imports, particularly in contrast with ROW, for which a large portion of EU exports is destined. The relatively small tariff reductions in ROW result in a considerable improvement in terms of trade for the region at the expense of EU's export prices. Given these three factors, it is not surprising that export prices fall more than import prices for all industrial goods traded by the EU.

The increases in quota rent transfers from industrialized countries to developing countries are mirrored in the changes in the export tax equivalents of MFA quotas. Non-MFA reforms strengthen import demand for textiles and clothing in North America and the EU relative to supply of these exports by developing countries. This drives up the export quota rent premiums (Table 10.6). In the context of the Uruguay Round reform, this may mean that developing countries will face increasing restrictions on their textile and clothing exports during the period of transition. Much, of course, depends on how rapidly and effectively industrialized countries bring their textile and clothing sectors under the normal GATT rules. Whether tariff reductions on textiles and clothing will proceed before substantive tariffication of quota restrictions also makes a difference to the welfare of developing countries. As noted earlier, the tariff cuts alone will benefit developing countries significantly even if the MFA is left in place. Given that inefficient exporters are likely to lose from the abolition of the MFA, they are probably better off from speedy non-MFA reforms and a slow phase-out of the MFA. For efficient exporters, however, they must balance the increased quota rents arising from a slow MFA phase-out against the efficiency gains from a speedy phase-out. Given that the gain from the complete abolition of the MFA is at least several times larger than increased quota rents, these exporters are likely to benefit more from a rapid elimination of the MFA.

The increase in rent premiums has important implications for the political economy of MFA reform. Because MFA quotas on exports from the NIEs have come to account for a much higher share of their exports than of exports from ASEAN, China, and South Asia, there is relatively little incentive for the NIEs to see the MFA abolished. Indeed, if the competitive position of the NIEs were to stay unchanged, they might well have been better off if the MFA remained in place beyond the Uruguay Round. This contrasts sharply with the situation in the mid-1980s, when the abolition of the MFA would have benefited virtually all developing countries, according to Trela and Whalley (1990) and Yang (1994a). In the mid-1980s, when textile and clothing exports from developing countries were dominated by the strongly constrained East Asian economies, all major developing country exporters had an interest in reform.

Effects of the complete Uruguay Round reform

Our final experiment, E4, simulates complete Uruguay Round trade liberalization. This not only allows us to assess the implications of the round for the world economy and its impact on the textile and clothing sector in particular, but also enables us to evaluate the contribution of MFA reform to the entire Uruguay Round package by deducting results from the previous experiment on the non-MFA reforms from those of the comprehensive reform (i.e., E4–E3, which is reported in the final column of Table 10.6).

The second set of entries in Table 10.5 summarizes the effect of the Uruguay Round on the output and exports of textiles and clothing. Comparing these entries with those from E1, we see that the predominant impact on production and exports of textiles and clothing came from MFA reforms, rather than from non-MFA reforms. In Australasia, however, non-MFA reforms had a greater impact on the textile and clothing sector because the initial tariffs on the sector were high and this region did not participate in the MFA. The clothing sector in the NIEs regains some ground from the substantial declines in production and exports following the abolition of the MFA. In addition, textile production and exports from the NIEs increased substantially from the pre–Uruguay Round MFA liberalization scenario, further reducing the adverse effect of MFA removal on their welfare. For countries other than Australasia and the NIEs, non-MFA reforms tend to amplify the effect of MFA reform. This is largely because tariffs on textiles and clothing are relatively high as compared with other manufactured goods, especially in industrial countries. Thus, for most countries, non-MFA reforms do not make adjustment in the textile and clothing sector any easier than if the MFA alone is liberalized.

The last two columns of Table 10.6 report the welfare effects of E4, the full Uruguay Round, and the difference, E4–E3. The latter represents the portion of E4 attributed to MFA reform. The global welfare gain from the comprehensive reform is around \$75 billion, of which nearly \$29 billion comes from the abolition of the MFA. For the world as a whole, the MFA reform accounts for 38% of total benefits of the Uruguay Round package. For the most affected countries, the share of the gain from MFA reform in the total gain is well above the world average. In fact, for these countries, the removal of the MFA is by far the most important reform. The MFA reform is of major importance to ASEAN, China, and South Asia, three of the most dynamic textile and clothing exporters in the last couple of decades. Even in North America and the EU, where agricultural reform is widely regarded as most important, MFA reform accounts for 84% and 55% of their total gains from the Uruguay Round, respectively. Non-MFA reforms are most important to Australasia, Japan, the NIEs, Latin America, and ROW. The reform of the MFA alone would in fact result in net welfare losses for some of these economies. This, nevertheless, highlights the vital influence of MFA reform in the overall welfare impact of the Uruguay Round trade liberalization on these countries.

It should be noted that the global welfare gain from MFA removal during the Uruguay Round is more than $1 billion larger than that arising from a pre–Uruguay Round reform (E1). The difference results from the fact that MFA quotas become more stringent following non-MFA reforms, as indicated by the increases in rent premiums shown under E3 in Table 10.6. Thus, abolition of the quotas after the other reforms have been implemented leads to a greater welfare improvement. Therefore, had the Uruguay Round failed to bring the MFA in the GATT framework, the annual cost of these bilateral quotas would have been even higher in a post–Uruguay Round world.

VI Conclusions

The decision to abolish the MFA in the Uruguay Round trade negotiations has been hailed as a great victory for the GATT principles of nondiscrimination and the elimination of quantitative restrictions. With agriculture also brought under the normal GATT rules, the global multilateral trading system has been substantially strengthened.

Our simulation results show that the phase-out of the MFA is indeed important. Global welfare gains from MFA reform are well over one-third of the total gains from a complete Uruguay Round trade liberalization scenario. For the dynamic Asian textile and clothing exporters the MFA is by far the most important trade reform in the Uruguay Round. This is even true for North America and the EU, where the textile and clothing sector is small and far less important than in developing countries.

The significance of MFA reform in the Uruguay Round also lies in the fact that the cost of the MFA would have increased had it been allowed to stay beyond the round, while agriculture is being liberalized and industrial tariffs are being reduced. This is because non-MFA reforms, if implemented alone, would lead to increases in the trade restricting impact of MFA quotas.

Our results also point to the possibility that the developing country textile and clothing exporters, with larger quotas relative to their production potential, may lose from the elimination of the MFA because of the increased competition from their more efficient competitors and the deterioration in their terms of trade. One advantage of eliminating the MFA in the Uruguay Round is that developing country exporters with high shares of their exports going to restricted markets are substantially compensated for their possible losses by the gains from the non-MFA reforms. Given that the MFA is to be abolished, the best policy option for these inefficient exporters is to speed up tariff reductions and agricultural liberalization. A slow phase-out of the MFA may increase their quota rent revenue, at least in the transition period of MFA phase-out, but this gain is likely to be small compared with that from speedier non-MFA reforms. Speedy non-MFA reforms are also in the interest of more efficient exporters, although an effective, earlier phase-out of the MFA remains paramount to their interest.

In the pre–Uruguay Round context, second-best considerations suggest that it may be in the best interest of industrialized countries to maintain high tariffs on textiles and clothing. In the post–Uruguay Round, however, they are far better off to reduce all tariffs rapidly, as well as to phase out the MFA as quickly as possible. With the removal of the MFA, the high tariffs become more costly. Yet, any attempt to delay the effective phase-out of the MFA will also result in higher costs because of the increased quota rent transfer to developing countries.

Overall, second-best considerations do not warrant slow implementation of either MFA reforms or non-MFA reforms. The comprehensive coverage of the Uruguay Round means that while most countries will benefit from a fast and effective phase-out of the MFA, countries that may lose from MFA reform will be subject to a minimum adverse income effect because of the substantial gains from non-MFA reforms.

Appendix: Determining whether a region will gain or lose from MFA liberalization

In this appendix, we consider the effects of a change in an export quota on the welfare of an exporting region. Since a region that exports subject to the MFA quota stands to gain from additional export demands and higher prices, but to lose from quota rent elimination, the net effect is unclear. In this appendix we attempt to determine the sign of this effect for particular supplying regions.

In the absence of distortions, the economy of each region can be characterized in terms of an expenditure function $e^i(p_w, U)$ which determines total expenditure in terms of the vector of consumer prices (p_w) and the level of utility (U), and a revenue function $r^i(p_w, V)$ which defines the value of output as a function of production prices and a vector of fixed endowments (V).

For each region, $Z^i(p_w U,V)$ gives the net expenditures on a commodity, where

$$Z^i(p_w,U,V) = e^i(p_w,U) - r^i(p_w,V). \qquad \text{(A10.1)}$$

Equation (A10.2) shows the trade market equilibrium condition for a commodity exported from region 0 to regions 1 and 2. Z_p^i are the partial derivatives of the net revenue functions ($e^i - r^i$) for regions $i(i=0,1,2)$ with respect to each region's trade price (p_w). Noting that e_p^i equals the Hicksian demand (which equals the Marshallian demand at equilibrium) and r_p^i equals the supply of the commodity, then Z_p^i represents net imports for region i, and

$$Z_p^0 + Z_p^1 + Z_p^2 = 0. \qquad \text{(A10.2)}$$

When exports from 0 to 1 are constrained by an export quota at the level of Q, the market equilibrium condition becomes:

$$Z_p^0 + Q + Z_p^2 = 0 \qquad \text{(A10.3)}$$

With the export quota, the exporter's welfare can be determined from equation (A10.4), where $(p-p_w)$ is a price wedge caused by the quota, p_w is the world market equilibrium price, p is the import price charged to the restricted market, and U is the initial level of utility in the exporting region. The quota rent revenue is given as $(p-p_w)Q$ to country 0. As a result, the income expenditure condition for country 0 becomes,

$$e^0 - r^0 - (p - p_w)\, Q = 0. \qquad \text{(A10.4)}$$

Define the burden, (B^j), as the additional financial inflow required to maintain a specified level of utility U^j in the exporting country under the distorted market situation as follows:

$$B^j = e^0(p_w, U^{jrb}) - r^0 - (p - p_w)\, Q = Z^0\,(p_w,U^j) - (p - p_w)\, Q. \qquad \text{(A10.5)}$$

Here utility is fixed exogenously at level j. Therefore B^j provides a money measure of welfare change.

By convention, a reduction in B^j is a reduction in the cost of achieving a given level of utility and hence an increase in welfare. Holding utility constant at level j, and considering the impact of a change in quota, the change in the burden or cost of maintaining the level of utility of the exporting country (dB) is given, up to a second-order approximation, as follows:

$$dB = Z_p^0 \frac{\partial p_w}{\partial Q} dQ - Q\left(\frac{\partial p_w}{\partial Q} - \frac{\partial p_w}{\partial Q}\right) dQ - (p - p_w)dQ$$
$$+ \frac{1}{2}\left[Z_{pp}^0\left(\frac{\partial p_w}{\partial Q}\right)^2 - 2\left(\frac{\partial p}{\partial Q} - \frac{\partial p_w}{\partial Q}\right)\right](dQ. \qquad \text{(A10.6)}$$

Dividing both sides of equation (A10.6) by the total value of exports (X), which is the sum of the export value and quota rent revenue, and manipulating terms results in equation (A10.7).

$$\frac{dB}{X} = \frac{1}{X}\left[Z^0_{pp}p_w\left(\frac{\partial p}{\partial Q}\frac{Q}{p_w}\right) - Qp\left(\frac{\partial p}{\partial Q}\frac{Q}{p}\right) + Qp_w\left(\frac{\partial p_w}{\partial Q}\frac{Q}{p_w}\right)(p - p_w)\,Q\right]\frac{dQ}{Q}$$
$$+ \frac{1}{2X}\left[2\left(\frac{\partial p_w}{\partial Q}\frac{Q}{p_w}\right)Qp_w - 2\left(\frac{\partial p}{\partial Q}\frac{Q}{p}\right)Qp + Z^0_{pp}\left(p_w\frac{\partial p_w}{\partial Q}\frac{Q}{p_w}\right)^2\right]\left(\frac{dQ}{Q}\right)^2, \quad \text{(A10.7)}$$

where $X = -[Z^0_p\, p_w - (p-p_w)Q]$ is the value of exports of the good in question.

Rearranging the right-hand side of equation (A10.7) yields:

$$\frac{dB}{X} = \left[\frac{(Z^0_p p_w)}{X}\left(\frac{\partial p_w}{\partial Q}\frac{Q}{p_w}\right) - \frac{Qp}{X}\left(\frac{\partial p}{\partial Q}\frac{Q}{p}\right) - \frac{(p - p_w)Q}{X}\right]\frac{dQ}{Q}$$
$$+ \frac{1}{2X}\left[2\left(\frac{\partial p_w}{\partial Q}\frac{Q}{p_w}\right)Qp_w - 2\left(\frac{\partial p}{\partial Q}\frac{Q}{p}\right)Qp + Z^o_{pp}\left(p_w\frac{\partial p_w}{\partial Q}\frac{Q}{p_w}\right)^2\right]\left(\frac{dQ}{Q}\right)^2. \quad \text{(A10.8)}$$

Further modifying equation (A10.8), by using the relation that total export revenue equals the sum of the value of exports at the world price plus the export rent revenue yields:

$$\frac{dB}{X} = \left(\left[-1 + \frac{Qp}{X}\right)\left(\frac{\partial p_w}{\partial Q}\frac{Q}{p_w}\right) - \frac{Qp}{X}\left(\frac{\partial p}{\partial Q}\frac{Q}{p}\right) - \frac{(p - p_w)Q}{X}\right]\frac{dQ}{Q}$$
$$+ \frac{1}{2X}\left[2\left(\frac{\partial p_w}{\partial Q}\frac{Q}{p_w}\right)Qp_w - 2\left(\frac{\partial p}{\partial Q}\frac{Q}{p}\right)Qp + Z^0_{pp}\left(p_w\frac{\partial p_w}{\partial Q}\frac{Q}{p_w}\right)^2\right]\left(\frac{dQ}{Q}\right)^2. \quad \text{(A10.9)}$$

Rewriting equation (A10.9), by replacing the value ratio expressions with value shares, and flexibilities, gives:

$$\frac{dB}{X} = [(S_Q - 1)e_{wQ} - S_Q e_{1Q} - S_R]\frac{dQ}{Q}$$
$$+ \left[(S_Q - S_R)e_{wQ} - S_Q e_{1Q} + \frac{1}{2X}Z^0_{pp}(p_w e_{wQ})^2\right]\left(\frac{dQ}{Q}\right)^2, \quad \text{(A10.10)}$$

where e_{wQ} is the flexibility of the world price with respect to the quota, e_{IQ} is the flexibility of the restricted market price with respect to the quota, S_R is the share of rents in total export value, and S_Q is the share of export value to the restricted market in the total export value defined as follows:

$$e_{wQ} \equiv \frac{\partial p_w}{\partial Q}\frac{Q}{p_w},\ e_{1Q} \equiv \frac{\partial p}{\partial Q}\frac{Q}{p},\ S_R \equiv \frac{(p - p_w)Q}{X},\ \text{and}\ S_Q \equiv \frac{Qp}{X}.$$

Recalling that a fall in B corresponds to an increase in welfare, from equation (A10.10), it is clear that the first-order effects of an increase in the export quota depend upon: (1) the share of exports going to the restricted market times the effect on the price in the quota market, (2) the share of exports going to nonquota markets multiplied by the change in the world market price and (3) the share of quota rent revenues in total export returns.

For complete quota removal, quota rents go to zero and the third first-order term ($-S_R$) is eliminated as are the first two second-order terms. Under these circumstances, whether a region will gain or lose from liberalization depends upon the first two first-order terms and the final second order term in equation (A10.10). The first-order term, $(S_Q-1)e_{wQ}$, shows the impact of the rise in world prices on the welfare of the exporting country. The second term, $-S_Q e_{lQ}$, shows the impact of the decline in prices received in the restricted market on exporter's welfare. The quadratic second-order term, $(1/2X)Z^0_{pp}(p_w e_{wQ})^2$, shows the efficiency gains associated with output expansion following the rise in the world price.

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CHAPTER 11

Global climate change and agriculture

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I Introduction and overview

Global population is projected to rise from today's 5.3 billion to more than 8.3 billion by 2025, with about 85% of that population living in developing countries (World Bank 1992). If that population is to be fed and if standards of nutrition are to improve, production of food will need to be increased several times from present levels. Cropland expansion and technological progress in farm production and in the processing sectors will help in meeting this goal. However, there are concerns that we may be running short on land suitable for cultivation and that further improvements in yields may be harder to achieve. Another factor that has recently attracted attention is the likelihood of change in climatic conditions. Climate change is an ongoing process, and global or local climates have changed in the past. Much of the present concern over climate change stems from the perceived negative consequences that might result from an enhanced greenhouse effect.

Some climatologists have long argued that the accumulation of carbon dioxide (CO_2) and other greenhouse gases would give rise to global warming and other climatic changes. However, they are not able to predict the exact timing and severity of this greenhouse effect. The best that can be done is to perform simulations with general circulation models (GCMs) that incorporate current knowledge of climatic phenomena and produce internally consistent climate scenarios. In particular, the level of atmospheric CO_2 is increased in a GCM, and the GCM is simulated through time until climatic variables reach a new equilibrium.

General circulation models do not agree in all aspects of their predictions of climate under a CO_2-rich atmosphere. The Intergovernmental Panel on Climate Change (IPCC) provides the following summary of results on climate change (IPCC 1990; Houghton, Jenkins, and Ephraums 1990; and Houghton, Callander, and Varney 1992): (1) the global mean temperature is likely to increase by 1°C above the present value by 2025 and by 3°C before the end of the next century; (2) regional climate changes will likely differ from the global mean, especially the distribution of precipitation; (3) high northern latitudes will warm more than the global mean in winter; (4) global average precipitation will increase 3–15%; and (5) soil moisture is likely to increase in high latitudes, but it is likely to decrease in northern midlatitude continents in summer due to evaporation.

Some of the most important impacts of this type of climate change might be those felt by agriculture because agricultural production is fine-tuned to temperature and moisture conditions in terms of cultivation practices and inputs. The US Environmental Protection Agency conducted research to evaluate the impact of climate change on crop yields, for several GCM scenarios. Agronomists in 18 countries used crop yield models developed by the US Agency for International Development for its International Benchmark Sites Network for Agrotechnology Transfer Project (1989). Crop models calculate yields based on factors such as weather (e.g., temperature, rainfall, and solar radiation), soil data, and cultivation practices (e.g., planting date, planting density and irrigation, and fertilizer practices). The GCM scenarios were developed by three institutions: the Goddard Institute of Space Studies (GISS) (Hansen et al. 1983), the Geophysical Fluid Dynamics Laboratory (Manabe and Wetherald 1987), and the United Kingdom Meteorological Office (Wilson and Mitchell 1987). These climates are assumed to occur in the year 2060. Crop response models for wheat, corn, rice, and soybeans were run for current and $2\times CO_2$-equivalent climatic conditions at 112 sites. Site-specific yield results were weighted by current production to generate national yield estimates. They also evaluated the direct effect of CO_2 on photosynthesis, evapotranspiration, and crop growth. The results from this research are reported in a volume edited by Rosenzweig and Iglesias (1994).

Several authors have looked into the economic implications of climate change with emphasis on agriculture [see Reilly and Thomas (1993) for a review of the literature]. Most of these studies focus on particular countries and agricultural commodities, and they provide partial equilibrium measures of welfare impacts.

The work of John Reilly and associates (Tobey, Reilly, and Kane 1992; Reilly and Hohmann 1993; Reilly and Thomas 1993) emphasizes the global nature of climate change and the importance of adjustments due to international trade. Kane, Reilly, and Tobey (1991) used the *S*tatic *Wo*rld *P*olicy *Sim*ulation (SWOPSIM) model to evaluate the economic effects of climate change. SWOPSIM is a partial equilibrium model of supply, demand, and international trade for 22 food and agricultural commodities and 36 countries/regions of the world (Roningen 1996). The SWOPSIM framework measures changes in producer and consumer surpluses. It assumes that income changes are small and that nonagricultural sectors are not affected by the shock examined. Kane, Reilly, and Tobey modeled climate change as shifts in commodity supply functions resulting from changes in crop productivity.

Reilly, Hohmann, and Kane (1991) also used SWOPSIM, and they specified shifts in commodity supplies based on Rosenzweig and Iglesias (1994). They concluded that climate change is unlikely to disrupt the world's food productive capacity and that the economic effects of climate change are likely to be small. They also concluded that this result depends to a large extent on the expected direct effect of CO_2 on crop growth.

All this work has been conducted under partial equilibrium assumptions, yet climate change is expected to have a large effect on some counties. This chapter intends to extend previous work to investigate whether partial equilibrium welfare measures can offer a reasonable approximation of the general equilibrium welfare impacts due to climate change. Kokoski and Smith (1987) evaluated partial equilibrium measures of the welfare impact resulting from climate change in a single economy. Their study was based on a synthetic data base designed to resemble the US economy. Six traded commodities were identified: agriculture, energy, chemicals, consumer durables, construction, and services. They found that partial equilibrium welfare estimates closely approximated general equilibrium measures for the model representing the US economy, but not for a model constructed to represent a developing country. Also, Kokoski and Smith (1987) did not evaluate this problem in a global context.

The purpose of the present study is to provide a comprehensive evaluation of the likely impact of climate change on global agriculture, *using both general and partial equilibrium closures.* This permits us to evaluate better the degree to which previous studies may have over-or understated the true effects.

II Aggregated data base and productivity shocks

Table 11.1 shows the regional and commodity aggregation for this chapter. We combine the 24 Global Trade Analysis Project (GTAP) regions into 8 aggregates: Canada, the US, Mexico, the European Union (EU), China, the Association of South East Asian Nations (ASEAN), Australia, and the rest of the world (ROW).[1] Likewise, we aggregate the 37 GTAP commodities into 8 aggregates: rice, wheat, other grains, other crops, livestock, processed agricultural commodities, and manufactures and services. The aggregate processed agricultural commodity includes processed foods, fisheries, as well as beverages and tobacco, textiles, and leather and leather products.

For our simulations we use available information on the aggregate effects of climate change by agricultural commodity. We examine the GISS climate change scenario and we implement climate change as Hicks-neutral technical

Table 11.1. ***Regional and Commodity Aggregation***

Regional Aggregation	Commodity Aggregation
1. Canada	1. Paddy rice
2. US	2. Wheat
3. Mexico	3. Other grains
4. EU	4. Nongrain crops
5. China	5. Livestock
	Wool
6. Association of Southeast Asian Nations	Other livestock
Indonesia	
Malaysia	**6. Processed agricultural commodities**
Philippines	Fisheries
Singapore	Processed rice
Thailand	Meat products
	Milk products
7. Australia	Other food products
	Beverages and tobacco
8. ROW	Textiles
New Zealand	Leather, fur, and products
Japan	
Republic of Korea	**7. Mining and manufactures**
Hong Kong	Forestry
Taiwan	Coal
Argentina	Oil
Brazil	Gas
Rest of Latin America	Other minerals
Sub-Saharan Africa	Wearing apparel
Middle East & North Africa	Lumber and wood products
Eastern Europe & former Soviet Union	Pulp, paper, and print products
South Asia	Petroleum and coal products
All other countries	Chemicals, rubber, and plastic
	Nonmetallic mineral products
	Primary iron and steel manuf.
	Primary nonferrous metals
	Fabricated metal products nec.
	Transport industries
	Other machinery & equipment
	Other manufacturing
	8. Services
	Electricity, gas, & water
	Construction
	Trade & transport
	Other services (private)
	Other services (gov't)
	Ownership of dwellings

change in the crop sectors of each region. For example, if output, Q, is a function of two inputs, X_1 and X_2, exogenous technical change is modeled as:

$$Q/A_0 = f(X_1 * A_1, X_2 * A_2).$$

Parameters A_0, A_1, and A_2 model technical change, and output and inputs are measured in *market* units (i.e., Q, X_1, and X_2) or *augmented* units (i.e., Q/A_0,

X_1*A_1, and X_2*A_2). Hicks-neutral technical progress is simulated by an increase in parameter A_0 (i.e., a positive shock would be applied to the GTAP variable a_0), and it implies that more output will be produced for the same quantities of both inputs. Parameters A_1 and A_2 represent Hicks-input augmenting technical change.

The assumed impacts on crop productivity are shown in Table 11.2. They are based on Rosenzweig and Iglesias (1994), as published in Reilly, Hohmann, and Kane (1993), for 33 regions and 9 crops: rice, wheat, corn, other coarse grains, soybeans, other oilseeds, cotton, sugar, and tobacco. We have aggregated across regions and commodities to compute shocks for our aggregation based on quantity and price data for 1989 (Sullivan et al. 1992). The top half of Table 11.2 (part A), shows productivity impacts that do not incorporate the direct effect of CO_2 on crop growth. Here, the impact of climate change on yields is clearly adverse across all regions, with worldwide productivity falling by 16–26%, depending on crop. Regional differences are quite dramatic, with average Mexican productivity dropping by 43%, followed by ASEAN with a decline of 34%. At the other extreme is Canada, where average regional productivity is hardly affected.

When one accounts for the direct effect of CO_2 on crop growth, the impact of climate change on agriculture is quite different. These estimates, are reported in the bottom half of Table 11.2 (part B). With the exception of Mexico and ASEAN, the adverse consequences of climate change are now offset, if not reversed! Canadian agricultural productivity now increases by 24%, on average. Most of the simulations in this chapter are based on the estimates in part B, because we feel that these estimates are more complete than those in part A. However, in the last section of the chapter, we also do a simulation with the shocks that do not incorporate the direct effect of CO_2 on crop growth to examine the sensitivity of results to this assumption.[2]

Three points should be made with respect to our modeling of climate change. First, we interpret the results in Rosenzweig and Iglesias (1994) as Hicks-neutral changes in crop productivity, that is, climate change will affect the productivity of all inputs in GTAP in the same way, and the magnitude of this effect does not depend on the levels of these inputs. This assumption fits well with the specification of production functions in GTAP (i.e., no substitution between value-added and intermediate inputs), and the degree of commodity aggregation in our data. To relax this assumption, we would implement a more flexible production system, obtain agronomic information to specify properly the effects of climate change under various input levels, and further disaggregate intermediate inputs.

Second, our approach does not capture any changes in technology that may be adopted by farmers in response to climate change. This appears to be an appropriate assumption given the medium-term time frame of our analysis.

Table 11.2. *Climate Change Impacts on Crop Productivity (%)*

	Region								
Commodity	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	WORLD AVERAGE
A. Impacts do not Account for Direct Effect of CO_2 on Crop Growth									
Rice	0	-18	-43	0	-24	-35	-13	-26	-26
Wheat	-12	-21	-53	-12	-5	0	-18	-22	-16
Other grains	-5	-20	-43	-8	-21	-40	-16	-16	-18
Other crops	1	-15	-43	-10	-15	-35	-16	-23	-19
Regional average	-3	-17	-43	-9	-17	-34	-16	-22	
B. Impacts Account for Direct Effect of CO_2 on Crop Growth									
Rice	0	1	-24	0	-3	-8	-12	-8	-7
Wheat	27	-2	-31	8	16	0	8	5	6
Other grains	15	-16	-35	1	-14	-33	5	-3	-9
Other crops	26	14	-18	15	13	-11	9	2	6
Regional average	24	2	-24	11	3	-11	8	-1	

For most farmers in the world, implementation of changes in production technology would require a longer-run time frame.

Third, we do not consider the beneficial impact of potential expansion in arable land due to more favorable climatic conditions. However, to address this important issue satisfactorily, we would need to expand this study and say something about other limiting factors (e.g., soil conditions).

Table 11.3 reports a variety of summary information obtained from the aggregation of the GTAP data used in this study. This includes commodity-specific information on private household expenditure shares, regional quantity shares in world output, and demand and own-price elasticities of total demand. Throughout the paper we will draw on this information to aid in the interpretation of results. The production shares from part B of Table 11.3 have also been used to obtain the estimates of worldwide productivity effects reported in Table 11.2. For example, we can see that ROW and China account for 75% and 15%, respectively, of world rice production. Since both of these regions experience adverse productivity effects, even when the direct effect of CO_2 on crop growth is present, we see a worldwide decline in productivity for rice of 26% (part A) and 7% (part B), as reported in the last column of Table 11.2.

In contrast to rice, wheat production is more evenly distributed around the world, with ROW and the US producing 36% and 21%, respectively, of global production. Other important wheat producers are the EU and China. As a result, global productivity changes for wheat are dampened, relative to those for rice. In part A, there is a decline of 16% in part B, there is an average productivity increase of 6% worldwide. For other grains, ROW accounts for 43% of world production, and the US and China account for 21% each. As a result, global productivity for other grains is expected to decline by 18% in part A, whereas with the direct effect of CO_2 on crop growth, this decline is only 9%. For other crops, ROW accounts for 47% of world production. The US, EU, and China account for about 14% each. As a result, the world productivity for other crops is expected to decline by 19% in the absence of the direct effect of CO_2 on crop growth, but it increases by 6% when these are included.

In a climate change scenario where crop productivity is altered, the consequences for price will depend importantly on the nature of demands facing producers in each region. In order to obtain some insight regarding regional demands, it is useful to turn to the last block in Table 11.3, which reports partial equilibrium, own-price elasticities of total demand. In the GTAP model, each region produces a differentiated product, which faces a distinct set of demands due to the Armington assumption. Columns 1–8 in Table 11.3, part D, show own-price elasticities for each region's total demand. These elasticities incorporate: (1) substitution between domestic and foreign varieties; (2) changes in the regional composition of imports; and (3) changes in consumer demands due to price effects.

Table 11.3. ***Household Budget Shares, Production and Use Shares, and Partial Equilibrium Demand Elasticities (%)***

	Region								
Commodity	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	WORLD
A. Private Household Budget Shares									
Rice	0.001	0.002	0.001	0.013	5.020	0.306	0.001	0.504	
Wheat	0.012	0.008	0.001	0.141	2.131	0.467	0.001	0.158	
Other grains	0.008	0.018	1.485	0.132	5.504	0.427	0.014	0.422	
Other crops	1.052	0.549	3.169	0.581	11.251	5.792	1.064	2.197	
Livestock	0.256	0.150	1.411	0.935	10.623	1.915	0.583	1.144	
Proc. agr.	1.277	8.571	23.887	17.299	26.982	28.086	14.839	18.647	
Manufacture	18.776	16.282	15.461	16.122	17.739	18.827	16.524	16.181	
Services	68.614	74.418	54.581	64.774	20.745	44.176	66.971	60.742	
Column total	100	100	100	100	100	100		100	
B. Production Shares									
Rice	0.01	1.17	0.16	0.26	15.22	8.38	0.06	74.75	100
Wheat	6.50	20.94	1.18	17.30	14.67	0.84	2.94	35.62	100
Other grains	1.66	21.60	4.81	5.89	21.18	1.34	0.45	43.07	100
Other crops	1.72	14.32	2.99	14.66	11.93	6.33	1.36	46.69	100
Livestock	2.32	15.02	2.56	33.90	7.80	1.94	1.70	34.76	100
Proc. agr.	1.83	15.22	2.11	28.09	4.76	3.24	1.06	43.68	100

Table 11.3. ***Household Budget Shares; Production and Use Shares; and Partial Equilibrium Demand Elasticities (Continued)***

Commodity	Region								
	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	*WORLD*
C. Use Shares									
Rice	0.01	1.02	0.17	0.36	15.22	8.36	0.05	74.80	100
Wheat	0.65	15.02	1.42	15.78	17.29	2.28	1.17	46.38	100
Other grains	1.31	17.63	5.26	5.78	20.37	1.50	0.22	47.93	100
Other crops	1.91	13.52	2.91	17.79	11.51	5.75	1.18	45.44	100
Livestock	2.15	14.92	2.57	34.33	7.62	1.99	1.17	35.24	100
Proc. agr.	1.86	15.52	2.18	27.99	4.20	2.98	0.99	44.27	100
D. Demand Elasticities									
Rice	-0.984	-0.392	-0.170	-0.642	-0.029	-0.009	-0.809	-0.017	-0.012
Wheat	-2.789	-0.881	-0.418	-0.453	-0.381	-1.128	-2.207	-0.898	-0.029
Other grains	-0.980	-0.438	-0.228	-0.415	-0.161	-0.427	-1.913	-0.586	-0.028
Other crops	-1.01	-0.763	-0.552	-0.806	-0.248	-0.905	-0.736	-0.467	-0.039
Livestock	-0.399	-0.186	-0.218	-0.159	-0.307	-0.242	-1.506	-0.202	-0.043
Proc. agr.	-1.038	-0.664	-0.639	-0.617	-1.327	-1.495	-1.344	-0.588	-0.211

Let us consider, for example, the impact of a 1% increase in the price for US wheat. From the second entry in the second column of Table 11.3 we see that, in partial equilibrium, this induces a 0.881% reduction in total demand for US wheat. Similarly, a 1% increase in the price for Australian wheat induces a 2.207% reduction in total demand for Australian wheat. Why are these demand elasticities for the same commodity so different, by region? As the reader may recall from Chapter 2, all the relevant partial substitution elasticities have the same value across regions, for any given commodity.[3] Therefore, it is not the substitution elasticities that determine the relative size of the elasticities in Table 11.3. It is the domestic use shares and the import and export volume shares that determine the size of the own-price elasticities. For example, the own-price elasticities for Australian wheat and other grains are large because: (1) Australia is not a major supplier to other regions; and (2) Australia exports a large share of its production.

The last column in part D of Table 11.3 shows price elasticities for global demand. For example, a 1% increase in all regional prices of rice will cause global demand for rice to decline by 0.012%. The elasticities of global demand for wheat and other grains are –0.029 and –0.028, respectively. The elasticity of global demand for other crops is –0.039. These elasticities are very small, reflecting the inelastic demands by households and firms for these raw products. Therefore, we can see that a 7% reduction in global rice productivity will cause the equilibrium world price to increase substantially, but equilibrium world supply will decline by a very small percentage. Nevertheless, we expect to observe differences in regional commodity price changes due to differences in productivity shocks and in regional demand elasticities. For example, the US and China produce equivalent quantities of other grains (Table 11.3, part B) and experience equivalent shocks in other grains productivity (Table 11.2, part B). However, we expect the US price for other grains to increase by less than the price for China because the US faces a more elastic demand than China.

III Experimental design

In this paper we report the results from four different simulations of the model. We begin by examining the effects of climate change under two multiregion, partial equilibrium (PE) simulations, and then we obtain general equilibrium (GE) results. For the two PE simulations, we apply the productivity shocks that account for the direct effect of CO_2 on crop growth (Table 11.2, part B). These are compared to the GE results based on the same set of shocks. Finally we run the GE simulation with the productivity shocks in Table 11.2, part A. This permits us to assess the relative importance of the direct effect of CO_2 on crop growth in evaluating the impact of global climate change for agriculture and worldwide welfare.

In the first PE simulation (PE1), we concentrate on the effects of climate change on agricultural commodities alone. In particular: (1) output prices and quantities supplied by crops and livestock are endogenous; (2) output prices and quantities supplied by the other sectors of the economy are exogenous; (3) land rents are the only endogenous primary factor price; and (4) we do not consider the effect of household income changes on consumer demands. Thus, in this simulation, the crops and livestock sectors will face six new prices (i.e., rice, wheat, other grains, other crops, livestock, and land rents), and they will optimally adjust output supply and input demands. Other sectors will not change output supply and thus they will not change their demands for primary factors or *composite* intermediates (although they will alter their pattern of sourcing of a particular farm commodity in response to relative price changes). Household demands for all commodities will change due to relative price effects. All sectors and households will change their composition of demands with respect to domestic and imported varieties of crops and livestock, and region of origin.

As productivity in the crops sector declines, the price of its output will increase, and this will induce an increase in demand for primary factors and other inputs. Land rents will increase in proportion to the importance of land in the sector under question. Higher land rents and increased feed costs will increase the cost of producing livestock commodities. Changes in comparative advantage of producing farm commodities and trading patterns will determine the final equilibrium.

The second PE simulation (PE2) is slightly more general than the first. Here, we allow the agricultural processing sector to respond to new economic conditions (i.e., its output price and production level are endogenous). As a consequence, the increased farm prices will be reflected in higher costs for the agricultural processing sector. This in turn will affect the demand for processed commodities, and hence the derived demand for farm products. As in simulation PE1, the price of land is the only endogenous primary factor price, and household income does not affect consumer demands.

The GE closure follows the standard closure for GTAP. In this medium-term simulation, all sectors are assumed to adjust to new economic conditions, all markets clear, and changes in household income are fully reflected in consumer demands.

IV Results

Partial equilibrium simulations

Table 11.4 shows results from the first PE simulation, in which the only endogenous prices are those relating to agricultural products. The first group

Table 11.4. ***Results from Partial Equilibrium Simulation 1***

	Region								
	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	WORLD
Producer Prices, %									
Rice	1.74	-0.78	50.04	0.00	3.73	13.42	15.42	11.99	10.73
Wheat	-19.24	1.53	59.83	-8.98	-17.09	-0.75	-8.89	-6.55	-7.30
Other grains	-10.85	19.92	79.94	-1.07	21.63	65.81	-1.23	4.80	14.91
Other crops	-20.72	-13.39	31.45	-14.45	-14.38	13.43	-9.28	-3.20	-6.21
Livestock	-3.87	3.83	17.59	-0.63	0.75	1.39	-0.15	0.59	1.00
Production, %									
Rice	0.75	5.01	-6.99	4.55	0.22	0.27	-4.57	0.30	0.33
Wheat	54.02	-10.99	-27.22	-1.16	1.22	-9.23	-0.17	-2.04	-0.44
Other grains	38.86	-3.44	-11.28	7.44	1.11	-13.88	34.42	5.80	2.08
Other crops	20.18	9.02	-15.14	8.42	2.30	-16.39	4.20	-3.28	-0.25
Livestock	3.49	-0.37	-3.49	0.22	0.12	-0.42	1.23	0.01	0.03
Exports, %									
Rice	27.42	38.47	-72.82	40.60	20.70	-18.43	-23.50	-19.39	10.50
Wheat	59.27	-34.51	-90.77	0.57	54.04	-26.58	-0.28	-8.01	4.55
Other grains	141.26	-13.85	-87.03	66.49	-9.40	-57.00	65.71	29.24	6.34
Other crops	79.00	31.50	-73.25	37.98	42.90	-50.65	20.98	-15.18	-3.41
Livestock	31.80	-6.45	-50.57	7.59	-0.65	-1.99	3.73	-0.51	1.62
Imports, %									
Rice	3.82	-16.99	126.77	-6.70	-13.63	13.22	21.21	17.28	
Wheat	-37.63	50.75	158.19	7.81	-10.26	4.08	22.83	1.72	
Other grains	-42.61	54.92	91.73	-21.30	68.86	50.11	-9.51	-8.98	
Other crops	-16.07	-23.61	86.88	-15.63	-21.67	33.64	-7.04	6.05	
Livestock	-8.01	9.81	43.95	-3.16	1.58	1.17	-1.70	-0.46	

Table 11.4. *Results from Partial Equilibrium Simulation 1 (Continued)*

	Region								
	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	WORLD
Factor Prices, %									
Land rent	14.84	-0.81	28.46	-4.20	-1.11	3.92	-1.39	1.06	
Agricultural Employment, %									
Labor	7.88	-0.56	14.64	-2.40	-0.81	2.04	-0.85	0.35	
Capital	7.88	-0.56	14.64	-2.40	-0.81	1.81	-0.85	0.29	
CPI, %	-0.18	-0.06	2.30	-0.08	-0.50	0.93	-0.10	-0.00	
Cons. Surplus, %	0.13	0.05	-1.90	0.06	0.29	-0.56	0.07	0.00	
Cons. Surplus, $	700	2493	-5620	3493	1309	-2016	183	-145	398
Income Change, $	-15	-1162	2953	252	-474	972	-45	4762	7243
Welfare Change, $	684	1331	-2667	3745	835	-1043	138	4618	7641

Note: Results are reported as changes from initial equilibrium. A dollar sign indicates that figures are in $US million. All other figures are in percentage changes This simulation is based on the shocks in Table 10.2, part B.

of entries in this table refers to producer prices in each region. These changes vary considerably due to the product differentiation assumption. The last column in this block reports average world prices. As expected, the world prices for crop commodities change substantially, but the equilibrium world supplies (next block of results) do not change very much. The price of other grains increases the most (14.91%) because the global productivity shock for other grains is the largest. World productivity for wheat and other crops increases; therefore world prices for these products decline.

On a region-specific basis, Canada and the EU experience some of the largest *increases* in crop productivity, and as a result their producer prices decline the most. Mexico and ASEAN experience the largest *declines* in crop productivity and their producer prices increase the most. These productivity changes are magnified in the trade changes, where relatively small flows must change substantially in order to bring regional supply and demand into equilibrium. Canada and EU become larger net exporters of all crop commodities, except wheat in the EU. Mexico and ASEAN become larger net importers of all crop commodities. More generally, productivity losses for net exporters reduce the quantity traded in the world market. In contrast, productivity losses for net importers would increase the quantity traded. For the GISS scenario, the net effect is that world trade in rice, wheat, and other grains increases, with the biggest increase in rice and other grains (10.50% and 6.34%, respectively). World trade in other crops declines by 3.41%.

In this simulation, changes in livestock output are largely determined by changes in other grains and other crops prices. For example, in the US the other grains price increases substantially and livestock output falls, because feed grain costs in US livestock production are relatively large. On the other hand, livestock output in Canada increases significantly due to lower feed grain prices.

Land rents increase in Canada, Mexico, ASEAN, and ROW because demand for farmland increases. Land rents decline by similar percentages in China and Australia despite the fact that the average productivity gain for China is only 3% but for Australia it is 8% (Table 11.2, part A). This happens because Australia faces more elastic demands than China does. (The cost share of land in agriculture is similar in both countries.)

Changes in consumer prices are not exactly the same as producer price changes, because consumers, as all other users, demand imported commodities whose prices change at a different rate. The consumer price index (CPI) summarizes the impact on the overall price level facing consumers. The CPI changes for the US, EU, and Australia are small relative to other regions because (1) their consumer budget shares for farm commodities are small (Table 11.3, part A), and (2) consumer prices do not change as much as in other regions.

We take the sum of changes in consumer surplus, taxpayer surplus, and producer surplus as an indicator of welfare change in a PE simulation. The latter two surpluses are captured in the income change reported at the bottom of Table 11.4. In all regions, except ROW, the change in consumer surplus dominates the change in producer and taxpayer surplus. Welfare declines in Mexico and ASEAN, the regions that experience large crop productivity losses (Table 11.2, part B).

The results in Table 11.4 depend on the specification of elasticities in GTAP. A set of parameters that is most important in determining our results is the Armington elasticities for commodity demands of foreign varieties. The results for regional producer prices in Table 11.4 suggest that our Armington elasticities produce trade patterns that are relatively rigid. This makes it possible for wheat prices in Canada, the US, and Mexico to diverge to such a large degree. The US does import a small quantity of Canadian wheat, and this prevents the US price from rising even more. But the amount of imports from Canada is not enough to force the US wheat price to decline as in Canada. If the trading patterns were more flexible, we would expect wheat prices in Canada, the US, and Mexico to follow the world price and decline by about 7%. At the same time, however, Mexico would reduce its cropland substantially (because it faces such huge productivity losses for crops) and turn into a giant feedlot. Obviously, this is not something that can happen in the medium term. Thus, we feel that the Armington assumption is appropriate for GTAP.

Table 11.5 shows results from the second PE simulation, where we allow the agricultural processing sector to adjust to new economic conditions, following climate change. Producer prices for processed agricultural commodities increase by 6.34% and 3.031% in Mexico and ASEAN, respectively, because (1) farm product prices increase substantially in these regions and (2) farm products represent a significant part of total cost for their agricultural processing sector.

Global demand for processed agricultural commodities declines by 0.17%. As a result, farm commodity prices do not increase as much as in PE1, and in some regions, agriculture cannot attract enough labor and capital to offset productivity declines due to climate change. This is more pronounced in Mexico and ASEAN, where agricultural employment of capital and labor increases by less than in PE1.

Turning to the welfare results at the bottom of Table 11.5, we find that welfare now deteriorates further in Mexico and ASEAN because of the larger consumer surplus losses, owing to processed agricultural commodity price increases. Also, their gains in income are smaller in PE2 than in PE1. Welfare gains in the EU are now much more pronounced ($10.3 billion in PE2 vs. $3.7 billion in PE1), and ROW's welfare gain turns into a slight loss, owing to declining consumer surplus.

Table 11.5. ***Results from Partial Equilibrium Simulation 2***

	Region								
	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	WORLD
Producer Prices, %									
Rice	2.09	-0.82	45.32	-0.08	3.93	10.34	15.77	11.63	10.22
Wheat	-19.19	1.50	55.49	-9.05	-16.95	-1.33	-8.80	-6.70	-7.41
Other grains	-10.67	19.87	75.20	-1.14	21.82	62.15	-1.12	4.63	14.57
Other crops	-20.55	-13.44	28.42	-14.52	-14.25	11.65	-9.16	-3.39	-6.50
Livestock	-3.83	3.82	15.29	-0.70	0.89	1.03	-0.07	0.69	0.95
Proc. agr.	-1.70	0.03	6.34	-1.14	-0.25	3.03	-0.75	0.94	0.28
Production, %									
Rice	1.76	4.73	-12.12	5.18	0.67	-4.53	-3.67	-0.33	-0.49
Wheat	52.38	-11.10	-30.46	-0.48	1.62	-9.18	-0.42	-2.44	-0.58
Other grains	39.43	-3.74	-13.49	8.11	1.38	-15.56	34.01	5.35	1.79
Other crops	20.86	8.70	-16.28	9.10	2.46	-16.81	4.14	-3.55	-0.36
Livestock	5.61	-0.25	-8.10	1.16	0.47	-3.44	2.04	-0.52	0.08
Proc. agr.	2.86	0.22	-6.41	1.20	1.36	-5.49	1.93	-0.77	-0.17
Exports, %									
Rice	23.34	35.53	-69.56	38.56	17.69	-10.95	-25.58	-19.14	9.45
Wheat	57.27	-35.20	-89.68	0.07	50.09	-26.91	-1.86	-8.46	3.44
Other grains	137.10	-15.98	-85.56	65.16	-12.80	-55.83	63.65	28.67	4.26
Other crops	75.55	29.39	-70.99	36.39	39.28	-48.51	17.05	-15.28	-3.90
Livestock	30.80	-8.39	-45.70	7.78	-1.23	-1.42	2.76	-0.68	1.08
Proc. agr.	10.66	1.81	-25.91	8.10	3.06	-12.12	6.01	-2.95	-0.11
Imports, %									
Rice	6.68	-16.34	99.84	-5.74	-12.33	4.55	25.89	16.28	
Wheat	-36.27	50.71	132.12	8.53	-9.63	0.91	24.89	0.83	
Other grains	-41.07	54.78	75.05	-20.61	70.07	40.77	-8.14	-9.81	
Other crops	-14.88	-23.02	71.96	-14.69	-20.60	26.72	-6.36	5.42	
Livestock	-7.51	10.27	28.46	-2.90	2.00	-0.62	-0.70	-0.83	
Proc. agr.	-2.55	-0.60	8.65	-3.82	-1.57	1.18	-1.85	1.38	

Table 11.5. ***Results from Partial Equilibrium Simulation 2 (Continued)***

	Region								
	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	WORLD
Factor Prices, %									
Land Rent	16.82	-1.25	18.56	-2.68	-0.39	-2.79	-0.48	-0.07	
Agricultural Employment, %									
Labor	8.94	-0.81	9.58	-1.53	-0.41	-1.55	-0.34	-0.26	
Capital	8.94	-0.81	9.58	-1.53	-0.41	-1.96	-0.34	-0.33	
CPI, %	-0.35	-0.05	3.55	-0.26	-0.49	1.57	-0.19	0.16	
Cons. Surplus, %	0.24	0.04	-2.89	0.19	0.29	-0.95	0.13	-0.11	
Cons. Surplus, $	1,274	2,313	-8,613	10,910	1,288	-3,397	348	-8,063	-3,940
Income Change, $	-3	-1,123	1,924	-546	-98	-319	-11	3,669	3,494
Welfare Change, $	1,271	1,189	-6,689	10,364	1,190	-3,716	337	-4,394	-447

Note: Results are reported as changes from initial equilibrium. A dollar sign indicates that figures are in $US million. All other figures are in percentage changes. This simulation is based on the shocks in Table 10.2, part B.

General equilibrium simulations

We now turn to the GE results in Table 11.6. The changes in output and trade are broadly similar to those in PE2; however, the same cannot be said of the welfare calculations, which are based on the regional equivalent variation (EV) associated with climate change. (Simple consumer, producer, and taxpayer calculations are no longer necessary.) Therefore, this section focuses on the welfare effects of climate change. First of all, note the two extreme cases represented by Canada and Mexico: Canada is a net exporter of agricultural commodities and it gains the most in crops productivity due to climate change; Mexico is a net importer of agricultural commodities and it loses the most in productivity. In Canada, agricultural production increases, and the nonfood part of the economy shrinks; the CPI increases because the prices of services and manufactures increase; but gains in producer surplus offset losses in consumer surplus, and welfare increases by about $US 2.6 billion. In Mexico, agricultural production declines, but the nonfood part of the economy shrinks too; the CPI increases because the farm and prices increase; both producers and consumers lose and welfare declines by about $US 8.2 billion.

A comparison of the welfare impacts from the PE simulations (Tables 11.4 and 11.5) with those from the GE simulation (Table 11.6) is provided at the bottom of Table 11.6. The first set of figures shows the degree to which the PE1 welfare results understate the GE results. In particular, they report $\{1 - EV(PE1)\}/EV(GE)$ multiplied by 100%. With the exception of the US, PE models that do not account for processed agricultural commodities (i.e., PE1) are likely to underestimate the welfare impact of climate change by more than 50%. For Canada, PE1 underestimates the welfare impact of climate change by 73.98%. With the exception of the US, inclusion of processed agricultural commodities is likely to improve measures of the welfare impact of climate change substantially: for Mexico, PE2 underestimates the welfare impact of climate change by only 19.15%.

Table 11.7 shows results from a GE simulation based on crop yield impacts that do not incorporate the direct effect of CO_2 on crop growth (Table 11.2, part A). World prices for all commodities increase; gains in producer surplus in some regions are not enough to offset losses in consumers surplus; and in all regions welfare declines. This leads us to the same conclusion as that of Reilly, Hohmann, and Kane (1993), namely, that the direct effect of CO_2 on crop growth will reduce substantially the adverse effects of climate change and it is important to account for it properly.

V Summary and conclusions

This chapter has used an eight-region, eight-commodity aggregation of the GTAP model of global trade to estimate effects of climate change and to

Table 11.6. ***Results from General Equilibrium Simulation***

	Region								
	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	WORLD
Producer Prices, %									
Rice	2.45	-0.77	44.06	0.19	4.28	9.84	15.95	11.56	10.18
Wheat	-18.90	1.56	54.28	-8.80	-16.66	-2.06	-8.63	-6.75	-7.31
Other grains	-10.34	19.94	73.63	-0.87	22.23	61.38	-0.96	4.55	14.59
Other crops	-20.25	-13.40	27.21	-14.29	-13.95	11.05	-8.99	-3.46	-6.50
Livestock	-3.45	3.88	14.18	-0.43	1.26	0.37	0.24	0.62	1.02
Proc. agr.	-1.17	0.09	5.16	-0.87	0.11	2.20	-0.50	0.85	0.30
Manufact.	0.52	0.06	-1.03	0.23	0.15	-0.55	0.22	-0.09	0.03
Services	0.57	0.07	-1.39	0.28	0.30	-0.98	0.27	-0.11	0.05
Production, %									
Rice	1.04	4.66	-11.41	4.89	0.53	-3.39	-4.01	-0.24	-0.35
Wheat	51.28	-11.03	-29.55	-0.61	1.46	-8.67	-0.60	-2.11	-0.54
Other grains	38.34	-3.78	-13.03	7.90	1.19	-14.85	33.70	5.57	1.85
Other crops	20.02	8.62	-15.85	8.72	2.22	-16.01	3.92	-3.44	-0.33
Livestock	4.95	-0.28	-7.55	1.03	0.32	-2.71	1.71	-0.41	0.07
Proc. agr.	2.25	0.19	-5.90	1.05	0.89	-4.27	1.62	-0.66	-0.15
Manufact.	-1.35	-0.04	1.84	-0.29	-0.09	2.01	-0.41	0.18	0.01
Services	0.08	0.02	-0.83	0.09	0.27	-0.20	0.05	-0.01	0.02
Exports, %									
Rice	21.53	35.18	-68.47	37.02	16.06	-9.29	-26.04	-18.85	9.40
Wheat	56.10	-34.94	-89.29	-0.37	48.88	-24.21	-1.96	-7.65	3.25
Other grains	134.65	-16.05	-84.96	63.99	-13.59	-54.70	63.31	29.54	4.06
Other crops	73.11	29.11	-69.96	35.10	37.53	-47.45	16.26	-15.02	-3.86
Livestock	28.92	-8.88	-42.75	6.52	-2.73	0.83	2.27	0.10	0.83
Proc. agr.	7.88	1.48	-21.39	6.65	1.28	-8.50	4.67	-2.46	-0.12
Manufact.	-2.79	-0.31	6.27	-1.36	-0.86	3.13	-1.21	0.59	0.09
Services	-2.20	-0.36	5.68	-1.34	-1.55	3.68	-1.19	0.43	0.03

Table 11.6. ***Results from General Equilibrium Simulation*** *(Continued)*

	Region								
	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	WORLD
Factor Prices, %									
Land rent	15.76	-1.29	18.64	-2.75	-0.33	-1.55	-0.80	0.08	
Labor wage	0.72	0.07	-1.40	0.33	0.49	-1.59	0.36	-0.15	
Capital rent	0.69	0.07	-1.67	0.36	0.67	-1.50	0.37	-0.15	
CPI, %	0.16	0.01	2.35	-0.01	-0.20	0.84	0.04	0.07	
Income Change, %	0.70	0.06	-0.98	0.35	0.45	-1.32	0.35	-0.09	
Welfare Change, %	0.50	0.04	-2.78	0.29	0.54	-1.73	0.26	-0.12	
	2,629	2,026	-8,273	17,253	2,397	-6,216	681	-8,958	1,539
EV, Welfare Comparison, %									
for PE1	73.98	34.30	67.76	78.29	65.16	83.22	79.74	sign change	
for PE2	51.65	41.31	19.15	39.93	50.35	40.22	50.51	50.95	

Note: Results are reported as changes from initial equilibrium. A dollar sign indicates that figures are in $US million. All other figures are in percentage changes. This simulation is based on the shocks in Table 10.2, part B. The figures for the partial/general equilibrium comparison of welfare impacts are computed as: 100*{EV(GE) - EV(PE)}/EV(GE).

Table 11.7. ***Results from General Equilibrium Simulation*** *(without direct effect of CO_2 on crop growth)*

	Region								
	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	WORLD
Producer Prices, %									
Rice	11.51	28.64	128.50	4.23	50.02	80.53	30.31	59.61	59.31
Wheat	24.24	33.03	169.01	20.44	11.51	5.35	33.48	41.49	30.98
Other grains	15.37	31.54	123.50	14.24	42.52	97.29	32.32	31.04	36.99
Other crops	7.94	27.53	115.83	17.15	29.86	76.71	33.29	46.94	39.78
Livestock	8.48	12.03	33.20	3.49	12.78	10.78	7.66	10.66	8.98
Proc. agr.	3.68	5.60	14.88	3.80	11.53	19.33	5.74	10.95	8.26
Manufact.	1.07	0.50	-1.61	0.68	0.57	-1.13	1.13	-0.25	0.20
Services	1.14	0.53	-2.42	0.69	-0.23	-3.04	1.18	-0.65	0.08
Production, %									
Rice	24.88	6.97	-20.61	32.98	-4.01	-16.90	15.18	-3.61	-4.69
Wheat	16.83	-2.17	-42.29	8.65	-3.75	11.37	-7.35	-13.15	-4.37
Other grains	21.59	1.21	-22.01	11.29	-3.50	-26.95	0.47	-3.87	-3.03
Other crops	36.35	9.24	-24.28	21.78	-1.91	-25.25	6.06	-7.84	-2.02
Livestock	4.68	0.55	-15.24	2.37	-9.68	-14.52	2.32	-5.20	-2.31
Proc. agr.	3.82	0.39	-12.67	2.74	-11.85	-20.97	2.11	-5.90	-3.33
Manufact.	-2.58	-0.70	2.21	-1.32	-4.85	2.83	-2.71	-0.46	-0.85
Services	-0.35	-0.33	-2.22	-0.78	-4.73	-2.28	-0.57	-1.10	-0.84
Exports, %									
Rice	201.94	51.24	-83.40	319.67	-6.36	-58.70	57.47	-42.78	1.37
Wheat	18.38	-6.80	-95.59	38.45	76.12	98.78	-14.20	-30.24	1.84
Other grains	65.71	6.85	-89.65	74.15	-14.11	-63.54	-2.36	-1.93	8.85
Other crops	175.83	45.05	-81.78	103.72	40.34	-58.27	34.36	-19.18	1.79
Livestock	18.31	-3.81	-56.09	33.49	-15.09	-6.26	4.19	-8.84	-0.78
Proc. agr.	22.74	13.41	-27.74	24.99	-13.92	-37.75	14.83	-11.24	-2.99
Manufact.	-5.34	-2.92	10.50	-4.32	-3.54	6.02	-6.62	1.21	-0.65
Services	-4.98	-3.89	9.32	-5.13	-2.08	10.13	-6.69	0.94	-1.12

Table 11.7. ***Results from General Equilibrium Simulation*** *(without direct effect of C), on crop growth)* *(Continued)*

	Region								
	CAN	US	MEX	EU	CHN	ASEAN	AUS	ROW	WORLD
Factor Prices, %									
Land rent	63.97	60.99	64.76	39.30	33.64	48.23	37.42	50.70	
Labor wage	1.09	0.31	-2.27	0.70	0.06	-5.64	1.21	-1.15	
Capital rent	1.13	0.54	-3.18	0.48	-5.52	-6.21	0.68	-1.55	
CPI, %	1.57	1.14	7.58	1.46	13.29	8.68	2.19	3.16	
Income Change, %	1.26	0.44	-0.85	0.14	0.25	-2.89	1.59	-0.38	
Welfare Change, %	-0.02	-0.56	-6.70	-1.02	-7.23	-7.59	-0.21	-2.48	
EV, $	-93	-29,499	-20,356	-60,323	-33,596	-28,149	-533	-180,957	-353,505

Note: Results are reported as changes from initial equilibrium. A dollar sign indicates that figures are in $US million. All other figures are in percentage changes. This simulation is based on the shocks in Table 10.2, part A.

illustrate differences between partial and general equilibrium welfare impacts. Climate change is likely to affect human societies and natural ecosystems in several ways. Here, we have concentrated on the effects of climate change on agriculture. Furthermore, we examine the medium-term effects of climate change on world agriculture as it is today, and we have not accounted for possible future changes in government policies, technology, and population.

We applied direct impacts of climate change based on the Goddard Institute of Space Studies climate change scenario, and we implemented climate change as Hicks-neutral technical change in the crop sectors of each region. These climate change shocks are applied both with and without the direct effect of CO_2 on crop growth to examine the sensitivity of our results to this assumption. The base case accounts for the direct effect of CO_2 on crop growth, and these results suggest that the average consumer in most regions will have to pay higher prices, with Mexican and ASEAN consumers paying 2.3% and 0.8% more, respectively. Consumer prices in China are projected to decline by 0.2%.

Overall, welfare in Mexico and the ASEAN countries is estimated to decline by 2.7% and 1.7%, respectively. All other regions experience a relatively small increase in welfare, ranging from 0.06% for the US to 0.54% for China. Welfare in ROW will decline by 0.12%. Assuming that Mexico, ASEAN, and ROW are compensated by the regions that gain, the world as a whole would experience a very small increase in welfare.

Canada and, to a lesser degree, Australia are expected to increase their market shares in exports of agricultural commodities in general. The US is projected to increase its dominance of the rice trade. Despite significant loses in productivity for some crops, *world* demand (and production) for crops will change little, because final demand for farm commodities is quite inelastic. Thus, commodity prices for crops change substantially. However, the impact on consumers is blunted because they tend to consume processed agricultural commodities that require a variety of nonfarm inputs, the prices of which are not affected by climate change.

Our results also suggest that it is important to account properly for the direct effect of CO_2 on crop growth. If this is *ignored*, the impact of climate change is much more damaging. Welfare declines in all regions, with ASEAN, China, and Mexico losing about 7% of real income.

Finally, we show that partial equilibrium models that incorporate processed agricultural commodities are likely to produce satisfactory results for prices and quantities. However, these models will show welfare impacts that are substantially smaller than those from general equilibrium models because they likely do not capture the effects on labor and capital markets.

NOTES

1. We have modified the GTAP data for primary factor payments in Mexican agriculture because land rents appeared to be very low. In particular, we changed the

distribution of primary factor payments to reflect the GTAP data for Argentina and Brazil, where land rents and labor wages account for 37% and 26%, respectively, of primary factor payments. Capital rents account for 37% of primary factor payments.

2. Wolfe and Erickson (1993) note that full realization of CO_2 benefits requires optimal field conditions with respect to access and timing of irrigation and chemical inputs, and that such ideal conditions may not obtain in many developing countries.
3. The compensated price elasticities of demand for the private household differ by region, but they do not affect the relative size of the elasticities in Table 11.3, because private households consume a very small portion of domestic production of raw agricultural commodities.

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CHAPTER 12

Environmental policy modeling

Carlo Perroni and Randall Wigle

I Introduction and overview

One of the goals of the Global Trade Analysis Project (GTAP) is to make a versatile, well-documented "consensus" model broadly available. The advantage of such a tool is that it can help focus discussion on the economics of the analysis, rather than the mechanics of model formulation and solution. Although this model is reasonably versatile, no numerical model can be truly all-purpose, and GTAP is no exception. Of particular relevance to this chapter are environmental externalities and abatement costs, which GTAP does not currently incorporate. The goal of the exercises we present in this chapter is to illustrate how GTAP can be used to analyze issues that are not directly accommodated by the model. This work is meant to be illustrative rather than definitive; in other words, we are not arguing that the model we use is the best model; rather, we wish to illustrate how simple adaptations to an existing model structure can permit better insight into environmental policy issues.

This work is also motivated in part by studies cited in the popular press containing statements such as:

- Carbon taxes would cost the US economy 4% of gross national product (GNP).
- Environmental regulation would lead to reduced imports because they distort the economy.[1]

Often, the bases of such statements are simulation models, most of which have one or both of the following characteristics:

- There is no treatment of environmental feedbacks to the economy (particularly benefits of cleanup).
- There is no abatement technology.

As a practical matter, much analysis of environmental policy issues will be done in models without these features, and one objective of this chapter is to note the kinds of errors that cannot be avoided in such cases. However, we also show here how a computable general equilibrium (CGE) model without abatement or environmental benefits can be used to achieve better representation of the consequences of environmental policy. We concentrate on simple ways of representing an (absent) abatement technology for the analysis of emissions fees, and we also note how the welfare effects of the policy are changed by making allowance for benefits from abatement. Finally, we note the limitations of this approach.

II Purely "economic" models

In models like GTAP, the focus is normally on the interrelation between policy variables (taxes, subsidies, or quantity restrictions) on various economic magnitudes, such as employment, trade, or income. They may also abstract from several types of unmarketed goods, or nonmarket transactions. In the current context, the damages done to the environment by firms can be seen as important unmarketed inputs used by the firms. The firms damage the environment by their emissions but are not required to bear all (or perhaps any) of the costs of that damage. A similar argument could be made for positive externalities as unpriced outputs from firms.

The absence of environmental features in GTAP complicates the process of analyzing environmental policy for a number of reasons, to be discussed below, so why would one want to use an existing model like GTAP for such a purpose? Typically, analysts face a trade-off between a model with all the desirable model features (e.g., explicit treatment of abatement and emissions), and the level of industry detail or the quality of policy data and parameters in the model. In such circumstances, it may be advisable to use GTAP for some aspects of analysis or use a model like GTAP in tandem with a special purpose model that may lack some other important policy information that could interact with environmental policies.

III Benefits from abatement

Implicit in models without environmental benefits is the assumption that environmental feedbacks to the economy (particularly through preferences and utility) are separable from those market transactions forming the core of the model. This approach applies to many models addressing issues ranging from carbon taxes to environmental regulation schemes.[2] In some cases this omission makes sense, although at least four types of interactions may be missed by such models:

1. Changes in the relative valuation of the public good compared to private goods.
2. Changes in relative prices of goods occasioned by the shift of consumption shares and by the resulting shifts in intermediate use.
3. Changes in consumption patterns caused by changes in environmental quality. These changes can include not only reduced consumption of private goods to isolate individuals from poor environmental quality, but also changes in consumption patterns between substitutes and complements for environmental amenities.
4. Interactions between abatement activities taken by firms and private mitigating expenditures such as buying water purifiers or household air cleaners.

By way of an example of these last two interactions, suppose that instead of walking downtown you take your car to avoid the pollution. You shut the car windows and turn the air conditioner on. In doing so you contribute to pollution. In this case the social "cost" of abatement could be very small, since if everyone paid a small amount for abatement, they might not need their air conditioners. Without the air conditioners on, the pollution would be less, and abatement would be less costly. Truly evaluating the social cost of abatement in this case requires that the feedback through the benefit side be taken into account.

In a similar way, models that have no explicit abatement activities (but only model the effects of emissions fees or environmental regulations as output taxes) miss the interactions between abatement activities and other activities in the economy. Abatement activities typically have an input mix different from the polluting sector.

From a modeling perspective, we believe there are several specific limitations to which these problems may be traced:

1. Absence of benefits accruing from environmental cleanup
2. Improper specification of benefits evaluation
3. Absence of abatement technologies (implicit or explicit)
4. Improper specification of abatement technologies

In this chapter we look only at how one might remedy two of these problems, namely, the absence of an abatement technology, and some treatment of the benefits of abatement. As noted above, we feel that many models not designed for environmental policy could be used to generate some insights when used carefully, particularly when a more sparse special purpose model is available as a complementary tool.

The general approach to linking GTAP with a special purpose model for environmental policy is shown in Figure 12.1. We begin with a generalized

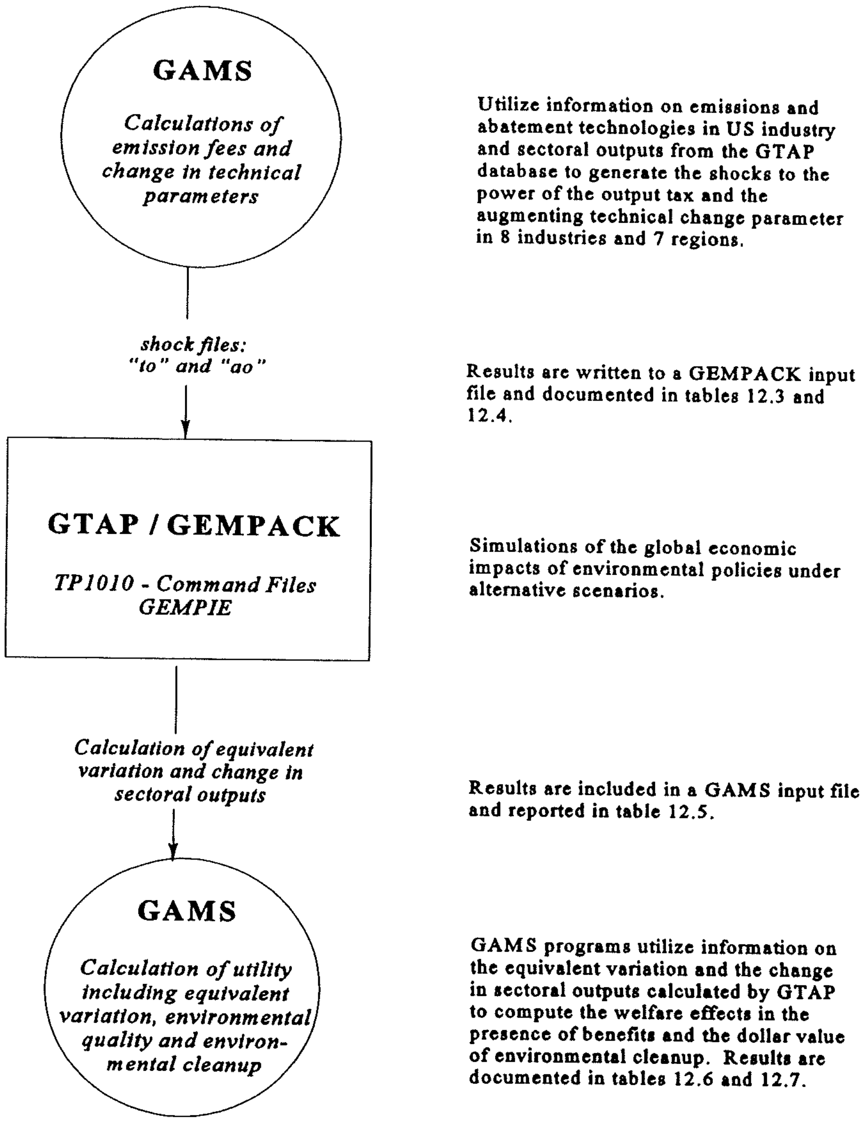

Figure 12.1. Computational procedures for environmental policy analysis using the standard GTAP model.

Table 12.1. *Commodity and Regional Aggregation*

Good	Description	Region	Description
AGR	Agriculture	OHI	Other high income
FDM	Food manufacturing	NAM	Canada and US
RSC	Primary industry	JPN	Japan
CLO	Textiles and clothing	EU	EU
DRT	Dirty industry	MID	Middle income
FMN	Final manufacturing	CHN	China
SVC	Traded services	LOW	Low income (<$2000)
NTS	Nontraded services		

algebraic modeling system (GAMS) program that calculates the "shocks" to GTAP that are necessary in order to achieve a given combination of emission fees and abatement. These shocks are implemented in GTAP, and the resulting changes in sectoral output and equivalent variation associated with market goods are then used as inputs into a third step. This final exercise is also implemented in GAMS and permits the user to calculate welfare changes that take account of environmental quality and clean-up costs.

IV Aggregation

In this application, we adopt the eight-good, seven-region aggregation described in Table 12.1. Commodities are grouped into agriculture, food manufacturing, primary industry, textiles and clothing, dirty industry, final manufacturing, and two service sectors that share a similar level of pollution. Since the willingness to pay for an improvement of environmental quality is correlated with income, the seven-region aggregation breaks out North America, Japan, the European Union (EU), and China, grouping other countries by income level.

V Experiments

We look at the implementation of a set of emissions fees aimed at reducing the damage done by industrial pollution. The particular experiment we concentrate on involves setting environmental taxes at their economically appropriate level. The necessary taxes differ between sectors due to differences in emissions intensities. Table 12.2 presents estimated damages per dollar of output of the industries in the model, and abatement expenditures.

Table 12.2. *Damages and Abatement per Dollar Output*[a,b,c]

Sector	Damages	Abatement Expenditures
AGR	0.011	0.005
FDM	0.001	0.003
RSC	0.010	0.011
CLO	0.009	0.003
DRT	0.021	0.009
FMN	0.004	0.003
SVC	0.015	0.001
NTS	0.015	0.001

Notes:

[a] The original source for the damage data is Lucas, Wheeler, and Hettige (1992; pp. 69—71). Damages represent the damage-weighted emissions (in equally toxic pounds per dollar of output) of US industries.

[b] Abatement costs are from Low (1992a). The data are again expenditures for dollar of output of US industries.

[c] All aggregated values are simple averages. Since the initial data did not include primary sectors or services, we assigned them values based on related sectors. In the case of AGR, this was based on averages across all sectors for damage data and abatement costs. In the case of services, abatement costs are taken from printing and publishing and damage data from beverages.

We assumed that the benchmark (per unit of output) emissions of a given industry were the same in all countries, but that the damages caused by emissions were valued differently. The high-income regions (EU, NAM, JPN, OHI) share a common valuation of the damages. The same amount of emissions that causes $1 of damage in these regions causes 20 cents of damage in China and the low-income region, and 50 cents in the middle-income region (MID). To complete our calibration, we assume a common overall rate of internalization of externalities in the initial equilibrium.[3]

The tax rates we report in Table 12.3 are indirect taxes in the initial data base; we refer to them as pollution taxes, for clarity. In this context, they represent the amount of "emissions fee" charged on the emissions resulting from $1 of output in the benchmark. These constructed benchmark pollution taxes range as high as 1.7% for primary industry in the high-income regions, and as low as 0.1% in the service sectors of the low-income regions (China and MID).

The damages and abatement data were used to generate a standard experiment, whereby emissions fees would be used to internalize fully the (local) environmental externalities. The resulting tax rates (after our experiment) are shown in Table 12.4. What is clear is that fully internalizing the damages in each sector involves raising the tax rates in some sectors and lowering them in others. The procedure we use to generate these tax rates is rather ad hoc, and these tax rates should be interpreted with caution.

Table 12.3. *Constructed Benchmark Pollution Taxes (cents per dollar)*

Sector	High	Mid	Low
AGR	0.8	0.4	0.2
FDM	0.5	0.2	0.1
RSC	1.7	0.8	0.3
CLO	0.4	0.2	0.1
DRT	1.3	0.7	0.3
FMN	0.4	0.2	0.1
SRV	0.2	0.1	0.1
NTS	0.2	0.1	0.1

Table 12.4. *Constructed Internalizing Pollution Taxes (cents per dollar)*

Sector	High	Mid	Low
AGR	2.6	1.3	0.5
FDM	0.2	0.1	0.0
RSC	2.3	1.2	0.5
CLO	2.1	1.1	0.4
DRT	4.9	2.4	1.0
FMN	1.0	0.5	0.2
SRV	0.1	0.0	0.0
NTS	0.1	0.0	0.0

VI Emissions fees and abatement

When abatement technologies are available, increases in emissions fees typically cause two types of response by firms. First, firms shift their production away from the production of dirty goods and toward cleaner goods. Second, firms tend to use cleaner technologies to avoid some of the taxes. In economic terms, this means using more market inputs to economize on the use of emissions. Thus, when an emissions fee is imposed, we expect to see an increase in the ratio of market inputs to output, and an increase in tax revenues.

It is possible to mimic these changes in the GTAP model, even though the model does not have any explicit abatement technology. This is done by simultaneously shocking technical parameters in the production functions and output tax rates. The idea is to reproduce the same percentage changes in quantities, prices, and input shares in GTAP as would be observed in a model containing an (albeit simple) abatement technology.[4]

VII Mapping between the "true" model and GTAP

When we think of abatement, we usually think in terms of using inputs to reduce the emissions associated with a given level of output. As long as the model is reasonably aggregated, a production technology implicitly representing abatement could be summarized as

$$Q = f(X, E), \tag{12.1}$$

where Q is output, X is the quantity of standard market inputs used, and E is the emissions produced. In the simplest case, the "price" of emissions would be the emissions fee charged, and cost covering prices (the unit cost) would be functions of the price of market inputs (PX) and the emissions fee (PE).[5]

If we assume that the input aggregate X has the same functional relation to market inputs as in the original model, and impose a functional form $f()$ on the relation between Q, E, and X, we can represent emissions fee shocks to the true model by shocking two of GTAP's variables, *ao* and *to*. These are, respectively, a neutral overall productivity shock applied industry by industry, and a change in the power of output taxes.[6]

We considered specifications of $f(X,E)$ that are weighted averages of the Leontief case (no substitution between X and E, so abatement occurs only by production shifting) and the Cobb–Douglas case (constant cost share of "abatement" compared to market inputs). The Leontief case is where no abatement (in the sense of lower emissions per unit of output) is possible. Our other discussions will concentrate on a case where abatement is easier than this extreme case, but not as easy as the Cobb–Douglas case (where a 1% increase in the effluent fee would reduce emissions by about 1%).[7]

The details are left to the appendix, where we show how implementation of a given percent increase in an emissions tax can be modeled in GTAP to give the same partial equilibrium output level, tax revenue, input ratios, and emissions effects as the "true" model by using the shocks and associated calculations listed in Table 12.8. Of necessity, these shocks will not yield the same general equilibrium results as the "true" model. For this, one would need the abatement and benefits features to be fully incorporated into the model. However, this method is clearly an improvement over ignoring abatement technologies.

VIII Results

The results that follow in Tables 12.5–12.7 represent the effects of implementing the emissions fees under two different assumptions about the production

Table 12.5. *Effects on Pattern of Production (% Change)*

	AGR	FDM	DRT	FMN	SVC	NTS
CASE A: No Abatement Substitution						
OHI	0.304	0.334	-1.785	-1.069	0.243	0.157
NAM	-0.590	-0.179	-1.074	-0.133	0.237	0.137
JPN	-0.143	-0.097	-0.690	-0.260	0.321	-0.088
EU	-0.442	-0.070	-1.442	0.211	0.384	0.141
MID	0.002	-0.171	0.619	-0.692	0.005	-0.016
LOW	0.153	-0.270	1.896	-0.728	-0.375	-0.132
CHN	0.115	-0.204	0.999	-1.745	-0.210	-0.083
CASE B: Abatement Substitution Present						
OHI	-0.091	0.048	-1.260	-1.325	0.045	-0.227
NAM	-0.649	-0.306	-0.775	-0.284	-0.003	-0.149
JPN	-0.626	-0.517	-0.333	-0.549	0.021	-0.449
EU	-0.460	-0.181	-0.963	0.076	0.080	-0.280
MID	-0.163	-0.388	0.930	-0.872	-0.221	-0.302
LOW	0.117	-0.396	1.887	-1.022	-0.530	-0.324
CHN	0.067	-0.402	1.017	-1.971	-0.367	-0.363

Table 12.6. *Welfare Calculations (1992 $US million)*

Region	Case A: GTAP	Case A: Benefits Present	Case B: Benefits Present
OHI (6.3)[a]	-455.7	2,263.1	578.4
NAM (5.2)	-811.6	43,472.6	14,759.8
JPN (8.6)	1,080.8	38,795.9	15,713.7
EU (6.5)	-835.5	55,512.4	20,403.4
MID (4.4)	172.3	21,752.5	8,963.9
LOW (1.9)	-297.7	3,522.5	1,587.6
CHN (3.1)	1,077.7	2,891.3	1,815.4
Total	-69.8	168,210.3	63,822.1

[a] Present share of environmental quality in utility, by region.

Table 12.7. ***Dollar Value of Environmental Cleanup (1992 $US million)***

Region	Case A	Case B
OHI	3,169.7	3,060.2
NAM	51,328.1	49,270.9
JPN	44,295.7	44,780.0
EU	65,705.0	65,334.0
MID	25,510.3	26,444.7
LOW	4,502.6	4,764.9
CHN	2,173.8	2,381.3
Total	196,685.1	196,036.0

Table 12.8. ***Summary Table***

Shocks		Leontief	Cobb–Douglas	Weighted
	to	$-\beta t$	0	$-\omega_L\beta t$
	ao	0	$-\beta t$	$-(1-\omega_L)\beta t$
Emissions				
	$\dot{e}$	0	$(\beta-1)t$	$(1-\omega_L)(\beta-1)t$
	$\dot{E}$	qo	$(\beta-1)tqo$	$\omega_L+(1-\omega_L)(\beta-1)tqo$

Notes:

β -- cost share of emissions in total cost; t -- proportionate change in emissions tax; ao -- technology shock variable; to -- proportionate change in the power of the output tax; qo -- proportionate change of sectoral output; ω_L -- weight on Leontief true model; $\dot{e}$ -- proportional change in emissions per-unit output; $\dot{E}$ -- proportional change in total emissions.

process that uses "emissions" and market inputs to produce output. In case A there is no substitution between emissions and market inputs (Leontief). The model shocks used in this case correspond exactly to what someone might do as a first step to analyze the effects of an emissions tax: they calculate a per-unit output tax equal to the emissions fee times the per-unit emissions.

In the other extreme case (Cobb–Douglas), the only model shocks are to the technical parameters (whereby the ratio of market inputs to output is raised to model abatement). A more likely intermediate case applies part of the (Leontief) emissions fee to output, and gives smaller shocks the technological parameters to mimic abatement. This is case B, whereby we assume the abatement process is an (equally) weighted average of Cobb–Douglas and Leontief technologies.

Sectoral impacts

The pattern of effects on production (Table 12.5) and patterns of trade are significantly different from one case to another. This is hardly surprising, since the ability to reduce emissions through abatement can reduce the cost disadvantage suffered by firms facing higher effluent fees. The table presents percentage output changes for selected sectors. Because GTAP is a global model, reductions in output in one region tend to be offset by increases in other regions. The biggest changes occur in the dirty industries, where the output tax is largest. In case A output in the "other" high-income economies falls by almost 2% while output in the low-income economies rises by a similar percentage.

Comparison of the results with and without abatement possibilities shows that global output of "dirty" manufacturing is less adversely affected in case B. There are also some sign reversals between the two sets of results, for agriculture and for services output changes in some regions. Thus, specifying one or the other abatement technology affects the qualitative response of the model to a given set of emissions fees.

Cost of environmental policy

The welfare evaluation from GTAP does not account for welfare changes corresponding to the improved environmental quality resulting from reduced emissions. In terms of that model, the emissions fees we are evaluating amount to competitive distortions in the market, so that global welfare losses are virtually guaranteed, unless they help offset some other preexisting distortion. Referring to the first column of Table 12.6, we see that world welfare falls by $69.8 million as a result of the introduction of the effluent fees. Four of the seven regions suffer welfare losses.

To take account of the benefits of improved environmental quality, we assume that each consumer has a constant elasticity of substitution (CES) utility function defined over the standard utility aggregate (as in GTAP) plus environmental quality, which is inversely related to the amount of environmental damages done by emissions:

$$\tilde{U} = F(U,Q). \tag{12.2}$$

Here F has the CES functional form, U is the equivalent variation from GTAP, and Q is the environmental quality, defined as follows:

$$Q = \overline{Q} - D, \tag{12.3}$$

where $\overline{Q}$ refers to the "endowment" of environmental quality and D is the damages from emissions.[8] The dollar value of damages is calculated given the emissions per unit output implicit in the specification of the production technology and the assumption that the marginal damage from emissions is constant. Therefore the damages also depend on the pattern of industrial output.

It was necessary to assume a number of values for the CES utility function F. In particular, we assumed that the share of initial (benchmark) damages to the endowment of environment quality ($D/\overline{Q}$) is 0.25, while the elasticity of substitution between goods (U) and environmental quality (Q) is 0.50. These assumptions are enough to determine the shares of environmental quality in utility shown in parentheses at the left of Table 12.6. Note that the largest shares are the wealthy countries. These range from 8.6% in the case of Japan, to 1.9% in the low-income economies.

With these parameters, the welfare effects of the emissions fees (adjusted to reflect the benefits of improved environmental quality) are given in the columns under the heading "Benefits Present." In case A, most of the welfare effects are very similar in magnitude to the reductions in environmental damages that result from the emissions fees reported in Table 12.7. Emissions fees reduce environmental damage by roughly 50% in the high-income regions. Given our paramaterization, this implies very high benefits from reduced emissions. The welfare estimates in both cases A and B in Table 12.6 show that all regions benefit from the taxes when environmental benefits are accounted for. Instead of a worldwide loss of $69.8 million, worldwide gains range from (case B) $63,822 million to $168.210 million (case A). Note, however, that if we had used the initial valuation of the damages, we would have concluded that the improvement in environmental quality (measured as the reductions in pollution damage) amounts to almost $200,000 million (Table 12.7), whereas the true gain reported in Table 12.6 is considerably less in *both* cases.

IX Qualifications

The calculations we have done suffer from a number of weaknesses that should be noted. First, the paramaterization of the value of general environmental damages (and hence of the benefits from emission reductions) depends on a number of preference parameters on which there is little evidence (particularly at the level of aggregation we are using here.)[9] Depending on the audience to be addressed, it might be preferable to use regular welfare calculations plus a separate "cleanup" calculation, as presented in Table 12.7.

For similar reasons, our calculations assume that the marginal cost of abatement is flatter than real marginal abatement cost curves. In practice the marginal abatement cost curve may become very steep when high levels of abatement are approached.[10] Once again, this can cause our assumed abatement response to be higher than it should be.

If GTAP were to be used regularly for such policy analyses, a preferable alternative to our approach would be to completely incorporate the benefits formulation and abatement technologies, along with corresponding data into the GTAP model.[11] This would remedy the problem of overestimation of benefits, and would improve the reliability of such calculations.

X Conclusion

The approach we employed here is still somewhat "back of the envelope," and our policy experiment is largely illustrative. Our intention has been to demonstrate a practical method of using an off-the-shelf model to analyze environmental issues, by supplementing this standard model with a set of outside data and calculations. Although this methodology has some limitations, we feel that it can be useful in circumstances where sufficiently reliable benefits, emissions, and abatement parameters are available to augment GTAP's rich economic and policy data.

Appendix: Introducing Abatement into GTAP

GTAP model

Effectively, we have the following production relation for each good in GTAP:

$$Q = kX$$

Where X is the normal aggregate of inputs with price Px and x refers to the input–output (IO) ratio. The relation between supply prices, market prices and taxes, and the technology shifters in GTAP is as follows:

$$ps = -ao + pm + to,$$

where pm is the proportionate change in the market price, ps is the proportionate change in the supplier's price, ao is the technological change shifter for output, and to is the percentage change in the power of the output tax. The "shocks" needed to implement the emission taxes should be determined such that the following items are identical between the GTAP model and the true model: pm, $\dot{x}$ (the rate of change in the input–output ratio), and the per unit tax revenue.

"True" Cobb–Douglas model

The true Cobb–Douglas model is summarized as follows:

$$pm = (1 - \beta)px + \beta\dot{\tau},$$

where $\dot{\tau}$ is the proportional change in the emissions tax (per dollar of output) and β is the share parameter of emission taxes in total costs. (The proportionate change in the emissions tax would be $\dot{\pi}+\dot{\alpha}+\dot{\nu}$, where ν is the valuation of emission damages, π is the rate of internalization of damages, and α is the amount of emissions per unit output. But for what follows, we will assume that $\dot{\tau}=\dot{\pi}$.) As a consequence of the cost shares, the following relations describe the proportionate changes of the per-unit input requirements

$$\dot{x} = \beta\dot{\tau}, \text{ and } \dot{e} = (\beta-1)\,\dot{\tau},$$

where $\dot{e}$ is the proportional change in emissions per unit of output.

To get the price change in GTAP to be the same as the price changes in the true model, we get the following:

$$\beta\dot{\tau} = -ao - to.$$

But note that we will also want

$$\dot{x} = -ao = \beta\dot{\tau}.$$

Therefore, the only shock to implement a change in emissions tax is to the technology parameter, *ao*. In the Cobb–Douglas case, the power of the (per-unit output) tax in GTAP is always constant at the initial value, and the tax revenue per unit of output changes only because the usage of X in production rises (mimicking substitution of factors for emissions). Therefore, the shocks we implement in the Cobb–Douglas case are:

$$to = 0 \text{ and } ao = -\beta\dot{\tau}.$$

The proportionate change in emissions per unit of output could be calculated as follows (see also Table 12.8):

$$\dot{e} = (\beta\ - 1)\,\dot{\tau}.$$

Leontief case

In this case, the relation between the proportionate changes in minimum cost and the changes in $\dot{\tau}$ are as follows:

$$pm = S_x px + S_e\dot{\tau}.$$

Note that initially S_x will correspond to $(1 - \beta\ )$ from the Cobb–Douglas case, and S_e will correspond to β . However, in the Leontief case these shares are not constant. X and e are constant in the true model. As a result, the shocks to *ao* and *to* represent a change in emissions tax in the Leontief are:

$$ao = 0 \text{ and } to = -\beta\dot{\tau}.$$

NOTES

1. This is not restricted to the popular press. Tobey (1993) talks about environmental regulations "distorting" trade patterns, and Goulder (1993) refers to the distorting effects of a carbon tax.
2. See, for example, Whalley and Wigle (1993) and Jorgensen and Wilcoxen (1993).
3. In other words, we assume that the initial abatement and emissions fees account for 50% of the value of damage done in the economy. We do allow these rates to differ between industries, as is common to most environmental regulatory schemes.
4. There are data on the input mix of the "abatement sector." See for example Nestor and Pasurka (1993). In this simple configuration, the abatement technology for a given sector uses the same input shares as production in that sector.
5. Environmental policies are not frequently set in terms of emissions fees; however, it is relatively straightforward to map between a number of other types of policies and corresponding emissions fees.
6. By the power of the tax, we mean 1 minus the tax rate. (In some cases this refers to 1 plus the tax rate.)
7. If one is fortunate enough to know the approximate reduction in per-unit emissions associated with a given percent tax increase, this information may actually be used to calibrate the model, by revealing the appropriate weighting between the two formulations.
8. The calibration of a utility function with environmental benefits is discussed in more detail in Perroni and Wigle (1994).
9. As a general observation, sensitivity analysis is essential to policy analysis because of the huge parameter uncertainty. Since our purpose here is purely illustrative, we decided not to do sensitivity analysis.
10. Our marginal abatement cost curve has a constant elasticity of marginal abatement cost with respect to abatement.
11. To do so, one would need access to the full GEMPACK software suite.

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CHAPTER 13

Multimarket effects of agricultural research with technological spillovers

George B. Frisvold

I Introduction and overview

There is an extensive literature on gains from agricultural research. Norton and Davis (1981) and Alston (1993) provide excellent surveys. Relatively few studies formally examine impacts of research in an international context, however. Even fewer have examined the effects of technological spillovers across regions. New technologies may reduce production costs, both in the country where they are developed and in other regions that can adopt these technologies or adapt them to local production conditions.

International spillovers are an important aspect of agricultural research. International research and assistance agencies such as the UN Food and Agriculture Organization (FAO), the World Bank, and the Consultative Group for International Agricultural Research (CGIAR) have missions that include the international dissemination of agricultural technologies. Also, the rise of multinational agricultural input suppliers means that adoption of agricultural innovations will not be confined to particular countries.

Spillovers also have implications for the setting of national research priorities. Because taxpayers incur the costs of domestic public research programs, there is interest in examining the distribution of research gains between the home country and the rest of the world. Research, such as plant breeding for particular production environments may be less transferable to other countries; chemical, mechanical, or processing innovations may be more transferable. National governments may desire to allocate resources to research projects with lower spillover potential to trade competitors; input suppliers or international research agencies may favor wider international adoption of technologies.

This chapter uses the Global Trade Analysis Project (GTAP) model to examine general equilibrium and open economy impacts of agricultural research. Results demonstrate how the size and distribution of net gains from agricultural research depend on (1) the trade position of the innovating country,

(2) technological spillovers, (3) the stage of production in the multistage process where technological change occurs, and (4) the factor bias of technical change.

The approach here differs from most returns-to-research studies that evaluate impacts of technological change in a single-commodity, partial equilibrium setting. Such studies often make two limiting assumptions. First, prices and production of all other commodities are assumed fixed. For example, it would be assumed that changes in the cost of producing corn would not alter market prices of wheat or livestock.[1] In contrast, the applied general equilibrium (AGE) framework allows for endogenous movements of regional prices and quantities in response to technological change.

Second, most studies assume that research results from one region do not affect productivity in others. For example, research to improve wheat yields in Canada would not contribute to increased yields in the US or new food processing technologies developed in Europe would not be adopted elsewhere. An important exception is Edwards and Freebairn (1984), who explicitly considered spillover effects by assuming that domestic research shifts out supply curves of both domestic producers and foreign competitors. Their study, however, considers spillovers in a single commodity, single stage of production setting. This chapter uses the approach of Edwards and Freebairn (1984) to simulate the shocks induced by spillovers. It extends that analysis by considering the full multiregion general equilibrium implications of such spillovers.

The chapter is planned as follows. Section II discusses multimarket effects of agricultural research. The AGE framework is introduced as a natural extension of previous multimarket approaches to assessing these effects. The merits of each approach are discussed. Section III discusses model aggregation and closure. Section IV examines the impacts of crop research with both multimarket and spillover effects. Section V examines the impacts of food processing research. Results of sections IV and V are compared to show how the size, sectoral distribution, and geographic distribution of research gains depend on the stage of production where productivity increases. Section VI examines biased technical change in the food processing sector. The assumption of factor neutrality in technical change often made in computable general equilibrium (CGE) model experiments is not an innocuous one. Changes in prices, sectoral employment, and returns to primary factor owners are highly sensitive to assumptions about the factor bias of technical change. Section VII summarizes major results and suggests directions for future experiments and analysis.

II Multimarket effects of agricultural research

Vertical market linkages

Several studies have examined agricultural production as a multistage process where on-farm production is linked backward to input suppliers and forward to food processors and distributors (Alston and Scobie 1983; Freebairn, Davis, and Edwards 1982, 1983; Mullen, Wohlgenant, and Farris 1988; Mullen, Alston, and Wohlgenant 1989). These studies provide a number of insights about how returns to buyers and sellers at different stages of the production process are affected by the factor bias of technological change as well as the stage of production where innovation occurs. The literature has focused on technological change in markets vertically linked to a single processed animal product, with little attention paid to horizontal linkages to markets for other agricultural commodities or to other regions.[2]

Horizontal market linkages

Studies of technological change in horizontally linked markets are of two types. In the first, markets for different commodities are horizontally linked when they are substitutes or complements in consumption and/or production. Not only does technological change affect production and consumption in the market where the innovation occurs, but also changes in price in the innovating market lead to changes in prices, production, and consumption in related markets. White and Araji (1991) examined horizontal linkages in the markets for beef and pork. They found that cross-market welfare effects of technological change on consumers were 15–60% as high as own-market effects, depending on which commodity experiences technological change. They also found that producer cross market effects were 37–128% of own-market effects.

The second type of study considers a single commodity in isolation but focuses on linkages between the domestic and world market for that commodity. A number of these make a stylized distinction between open and closed economies (Hayami and Ruttan 1995; de Janvry 1973; Akino and Hayami 1975; Romalho de Castro and Schuh 1977; Renkow 1994). In the open economy case, producers face an exogenous world price. Research-induced cost reductions allow domestic supplies to expand with no impact on world (and domestic) price. In the closed economy case, the commodity is assumed nontradeable and producers face a downward sloping (and usually inelastic) demand curve for crops. A basic result for this type of model is that domestic producers capture (virtually) all the gains from technical change in the open economy case; consumers are the main beneficiaries in the closed economy case. In the latter case, domestic producers may be made even worse off depending on the elasticity of demand and the type of supply curve shift assumed.

Other models employ an excess demand curve to allow domestic production to influence world and domestic price (Oehmke 1988; Edwards and Freebairn 1984; Martin and Havlicek 1977; Sarris and Schmitz 1981; Murphy, Furtana, and Schmitz 1993). The study by Martin and Alston (1994) employs the excess demand method and is rare in that it considers *both* linkages across commodity types *and* linkages between domestic and foreign markets.

Technological spillovers

New technologies originally developed in one country are frequently adopted in others. Thus, a country's research may lower costs of both foreign and domestic producers. Spillover benefits can be quite significant. Davis (1991) discusses cases in which spillover benefits exceed those accruing to the innovating country. This result may seem puzzling but can be explained in terms of the relative degree of specialization in production in innovating versus technology borrowing countries.[3]

Edwards and Freebairn's (1984) study was one of the first to examine spillovers for traded commodities. They consider the impact of research that lowers costs of domestically (Australian) produced goods but is also adopted by foreign producers. Research induces a downward shift in both domestic and rest of the world (ROW) supply curves for a commodity. The authors employ a linear, single-commodity trade model to examine how spillovers affect the size and distribution of welfare benefits between consumers and producers, both foreign and domestic. They find that a country's overall welfare gains from cost reductions in commodities it exports (imports) are lessened (increased) when cost reductions spill over to other regions.[4] They also find that producer gains are lessened by spillovers to other regions.

The AGE framework

The AGE approach is the most general framework for analysis of technological change. A multiregion AGE model includes all the types of multimarket extensions discussed above as special cases, accounting explicitly for price movements in both horizontally and vertically related markets. Edwards and Freebairn's (1984) approach to modeling spillovers is readily adaptable to an AGE application. This has a number of advantages over partial equilibrium and multimarket approaches. First, the model provides an internally consistent framework to avoid pitfalls of under- or overcounting welfare effects in a multimarket setting [see Alston (1993) for a discussion].

Second, a general equilibrium approach avoids fallacies of composition in the evaluation of the impacts of agricultural research as a whole. Most evaluations of the returns to research examine the impacts of a supply curve shift for a single commodity, holding technology, production, and prices of other commodities fixed. When evaluating impacts of pervasive technological change across multiple agricultural commodities, it is *not* valid to extrapolate from isolated partial equilibrium studies.

Third, the constant elasticity of substitution (CES)–constant elasticity of transformation (CET) specification of technology employed in AGE models provides an exact and theoretically consistent measure of producer gains to research. This is not always the case in returns to agricultural research studies that derive "approximate" welfare measures based on supply functions and supply shifts that are *ad hoc* or inconsistent with profit maximizing behavior.[5] In sum, the AGE framework helps ensure that one is modeling technology or measuring welfare in a comprehensive and theoretically consistent fashion.

Fourth, AGE models specify primary factor markets explicitly. One can thus directly examine impacts of technological change on returns to owners of land, accounting for shifts in land use and differential returns by type of land use. The AGE framework allows one to examine labor movements across sectors. Although impacts of new technologies on rural employment have long been an important policy issue (Cochrane 1958; Owen 1966; Schmitz and Seckler 1970; Brandt and French 1983), most partial equilibrium returns to research studies do not directly measure these impacts.[6]

In spite of the limitations noted above, partial equilibrium analysis of technological change can have a number of advantages over AGE analysis as well. First, there are fewer data requirements and usually more empirical estimates of parameter values and elasticities used in model calibration. Second, models can be run very quickly on small spreadsheet programs. Third, it is often easier to introduce more flexible functional forms or institutional details into simpler partial equilibrium models.

Partial equilibrium and general equilibrium analyses are complementary approaches. Partial equilibrium studies provide valuable insights about what factors (besides general equilibrium effects) matter for evaluating technological change. AGE models can provide information about when it is important to account for intersectoral feedback effects and when a simpler partial equilibrium approach is sufficient. AGE models can also be used to raise broader sets of questions than would be addressed in partial equilibrium analysis.

III Model aggregation and closure

Experiments in this chapter are based on a common five-commodity, six-region model using a full multiregion, general equilibrium closure. The commodity–region aggregation is shown in Table 13.1. The multiregion specification allows one to consider open economy effects of technological change. This aggregation also allows for explicit examination of the transmission of effects of technological change among crop, livestock, and processed food sectors of the economy. Crop output is an intermediate input into both livestock and food production; livestock is a major input to the processed food sector. Previous analyses of technological change in multistage production processes have focused on interactions only between the livestock and processed food sectors.

Table 13.1. *Commodity and Regional Aggregation*

Regional Aggregation	Commodity Aggregation
1. North America (NAM)	**1. Crops**
Canada	Paddy rice
US	Wheat
	Other grains
2. Australasia (ANZ)	Nongrain crops
Australia	
New Zealand	**2. Livestock**
	Wool
3. European Union (EU)	Other livestock
4. Southeast Asia (SEA)	**3. Processed Food**
Indonesia	Fisheries
Malaysia	Processed rice
Philippines	Meat products
Singapore	Milk products
Thailand	Other food products
	Beverages and tobacco
5. East Asia (EA)	
Japan	**4. Mining & Manufactures**
Peoples' Republic of China	Forestry
Hong Kong	Coal
Republic of Korea	Oil
Taiwan	Gas
	Other minerals
6. Rest of World (ROW)	Wearing apparel
	Lumber and wood products
	Pulp, paper, and print products
	Petroleum and coal products
	Chemicals, rubber, and plastic
	Nonmetalic mineral products
	Primary iron and steel manuf.
	Primary nonferrous metals
	Fabricated metal products nec.
	Transport industries
	Other machinery and equipment
	Other manufacturing
	5. Services
	Electricity, gas, and water
	Construction
	Trade and transport
	Other services (private)
	Other services (government)
	Ownership of dwellings

IV Impacts of crops research

Focus regions

Three regions are compared: Australasia (Australia and New Zealand), North America (US and Canada), and Southeast Asia. These regions differ with respect to their trade position in crops, the elasticity of demand for their crop output, and the importance of food and agriculture in overall consumption. Table 13.2 highlights some of these differences.

Table 13.2. *Economic Characteristics of Three Focus Regions*

	(ANZ) Australasia	(SEA) Southeast Asia	(NAM) North America
Crop exports / production[a] (%)	38.3	16.2	21.6
World trade share in crops[a] (%)	11.6	8.6	33.5
General equilibrium own price Demand elasticity for crops[a]	-1.6	-0.8	-0.8
Share of crops, livestock and food in consumption budget[a] (%)	14.1	34.0	8.4
Share of labor force economically active in agriculture[b] (%)	6.0	53.9	2.6

[a] Source: GTAP data base.
[b] Percentages are for 1988. Source: World Agricultural Trends and Indicators, 1979—89. Agricultural and Trade Analysis Division, Economic Research Service, USDA. Statistical Bulletin No. 815. All other figures are from the GTAP data base.

In Australasia, over 38% of crop production is exported. However, the region accounts for a relatively small percentage of world trade, so that the general equilibrium demand for crops is elastic (Table 13.2). North America represents a "large economy" case where production changes have more of an impact on world prices. This region's crop sector accounts for a third of world trade and faces inelastic demand for crop output. Southeast Asia produces crops primarily for domestic consumption and, like North America, faces inelastic demand for crops. It differs from the other two regions, however, in that food and agriculture account for a greater percentage of employment and consumption. Half of the labor force is economically active in agriculture; food and agricultural products account for one-third of consumption expenditures (Table 13.2).

Experiment 1: Technical change in a single region with no spillovers

This experiment (E1) examines the impacts of research that reduce the costs of crop production in a single region with no spillovers to other regions. In other words, other regions cannot make use of the innovating region's research results. The shock applied to the GTAP model is a 2% increase in the output augmentation parameter, *ao*, for the crops sector. The shock is applied in separate experiments to the three focus regions (ANZ, NAM, and SEA). The results of E1, E2, and E3 are presented in Tables 13.3 and 13.4. Table 13.3 presents impacts of technological change on domestic economy and global welfare. Table 13.4 presents a breakdown of impacts of technological change across region.

Table 13.3. *Impacts to Home and Other Regions of Research that Reduces Costs of Producing Crops*[a]

	E1a ANZ (1)	E1b NAM (2)	E1c SEA (3)	E2 ANZ (4)	E2 NAM (5)	E2 SEA (6)	E3a ANZ (7)	E3b NAM (8)	E3c SEA (9)
Output[b] (*qo*)									
Crops	2.32[c]	1.55	1.72	0.02	-0.15	0.58	-2.19	-1.66	-1.10
Livestock	-0.04	0.22	0.59	-0.25	0.04	0.59	-0.23	-0.18	0.00
Food	0.16	0.16	0.90	-0.22	0.03	0.85	-0.38	-0.13	-0.05
Manufacturing	-0.11	-0.05	-0.26	0.20	0.04	0.07	0.31	0.08	0.32
Services	0.01	0.02	0.05	0.04	0.03	0.13	0.04	0.01	0.08
Output Prices[d] (*pm*)									
Crops	-1.82	-2.02	-2.05	-2.78	-2.42	-2.98	-0.96	-0.40	-0.93
Livestock	0.08	-0.64	-0.14	-0.57	-0.93	-0.75	-0.64	-0.29	-0.60
Food	-0.09	-0.30	-0.55	-0.44	-0.48	-1.01	-0.35	-0.18	-0.46
Manufacturing	0.06	0.04	0.07	-0.09	-0.03	0.00	-0.15	-0.07	-0.07
Services	0.08	0.05	0.13	-0.09	-0.03	0.04	-0.16	-0.08	-0.08
Factor Prices[d] (*pfe*)									
Land in crops	0.53	-0.70	-0.34	-3.21	-3.97	-3.24	-3.64	-3.25	-2.86
Land in ivestock	0.28	-0.25	0.29	-2.04	-2.52	-1.81	-2.29	-2.26	-2.06
Wage rate	0.10	0.06	0.22	-0.09	-0.01	0.11	-0.18	-0.07	-0.11
Capital	0.09	0.06	0.21	-0.05	-0.03	0.16	-0.14	-0.08	-0.05
Employment (*qfe*)									
Crops	0.38	-0.53	-0.39	-2.44	-2.56	-2.06	-2.74	-2.02	-1.65
Livestock	-0.01	0.18	0.60	-0.59	-0.26	0.20	-0.59	-0.44	-0.39
Food	0.15	0.16	0.89	-0.20	0.02	0.89	-0.36	-0.14	-0.01
Manufacturing	-0.11	-0.05	-0.26	0.22	0.03	0.12	0.33	0.08	0.37
Services	0.00	0.02	0.05	0.06	0.02	0.18	0.06	0.00	0.13
Land Use (*qfe*)									
Crops	0.14	-0.10	-0.08	-0.69	-0.33	-0.18	-0.80	-0.23	-0.10
Livestock	-0.11	0.36	0.56	0.52	1.17	1.29	0.60	0.80	0.72
Equivalent Variation (*EV*)									
Domestic ($US m)	199	2,585	960	38	2,745	886	-157	180	-57
Total ($US m)	383	4,548	1,270	23,401	23,401	23,401	23,017	18,974	22,152
Domestic EV as % of total EV	52	57	76						

Note: Table column heads denote: top row-experiment; middle row-home region; Bottom row-column number.
[a] Technical change is a 2% increase in output-augmentation parameter in crops sector.
[b] All effects are to the home region unless otherwise stated.
[c] All values are percentage changes unless otherwise noted.
[d] All price changes are relative to the numeraire price of savings

Table 13.4. *Impacts of Crops Sector Technological Change Across Regions*

	Region Experiencing Cost Reduction[a]			
	E1a Australasia (1)	E1b North America (2)	E1c Southeast Asia (3)	E2 All Regions (4)
Composite Land Price (pm) Index (% Change)				
North America	-0.09	-0.60	-0.27	-3.65
EU	-0.03	-0.47	-0.13	-2.40
Australasia	0.39	-0.75	-0.30	-2.54
East Asia	-0.08	-0.82	-0.18	-3.16
Southeast Asia	-0.13	-0.78	-0.27	-3.06
ROW	-0.04	-0.54	-0.12	-2.89
Equivalent Variation (EV) (% Change)				
North America	7	2585	17	2745
EU	51	628	171	5651
Australasia	199	-42	-15	38
East Asia	109	1216	138	6471
Southeast Asia	10	1	960	886
ROW	7	160	-0	7610
Crop Sector Employment (qfe) (% Change)				
North America	-0.06	-0.53	-0.18	-2.56
EU	-0.04	-0.45	-0.12	-2.52
Australasia	0.38	-0.71	-0.34	-2.44
East Asia	-0.06	-0.53	-0.11	-2.15
Southeast Asia	0.08	-0.47	-0.39	-2.06
ROW	-0.03	-0.37	-0.08	-2.24
World Price (pw) (% Change)				
Crops	-0.04	-0.43	-0.15	-2.72
Livestock	-0.01	-0.18	-0.03	-0.64
Food	-0.01	-0.13	-0.04	-0.65

[a] Cost reduction achieved through 2% output augmenting technical change.

This 2% shock is of comparable size to the historic average annual rate of technological progress in US agriculture since the 1950s (1985; Bureau of Labor Statistics n.d.). Many other countries have maintained long-run rates of total factor productivity (TFP) growth close to 2%. Alternatively, the shock may be thought of as the rate at which crop productivity grows *relative* to other sectors. For example, in the US, TFP in agriculture has grown about 1% more per year than in other sectors over the last 15 years. Thus, the 2% productivity shock might represent the amount this productivity differential accrues over two years.

Australasia. A number of studies have discussed the impacts of technical change in small open economies (de Janvry 1973; Hayami and Ruttan 1985; Renkow 1994). In the stylized characterization of an open economy, producers face an exogenous world price; domestic and foreign crops, however, are perfect substitutes. Given perfectly elastic output demand, gains from innovation accrue wholly to domestic producers in the form of producer surplus.

The Australasian crop sector is similar but distinct from this stylized characterization. A relatively high percent of domestic crop production is exported (38.3%), but Australasia accounts for only about 11.6% of world crop trade. However, the Armington assumption of foreign and domestic product heterogeneity implies that output demand in the innovating sector will not be perfectly elastic, even for small suppliers of traded commodities. Therefore, welfare gains from research are not completely captured by domestic producers.

Technological change in the Australasian crop sector generates what de Janvry (1973) refers to as a "land price treadmill," in which rising returns to agricultural production are capitalized in land values. A 2% cost reduction in crop production increases crop output by more than 2% but reduces domestic crop price by less than 2%. Agricultural land values rise, with cropland prices rising more than land in livestock production. Land use and employment are shifted away from livestock production toward crop production.

There are also beneficial effects beyond the farm gate. Processed food production increases 0.16% and the associated price falls by 0.09%. Wages rise relative to prices of other purchased commodities. Consumers share gains with producers in the form of lower food prices, and labor enjoys a rising real wage.

Other regions experience significant economic gains (and losses) from innovation in Australasia. Domestic welfare, as measured by Hicksian equivalent variation, rises by over $199 million; foreign benefits are equal to $383 – $199 = $184 million (Table 13.3). Thus, Australasia captures about half of the total welfare benefits from its innovation. Innovation in Australasia has negative impacts on agricultural producers in other regions. Agricultural land prices, and hence producer surpluses, decline in all other regions (Table 13.4). Employment in the crop sector increases in Australasia, yet it declines in all other regions.

North America. North America represents a "large economy" case. Here production changes have more of an impact on world prices. Cost reductions of 2% in North American crop production cause world crop prices to fall 0.4% (Table 13.4). This region has a large home market for its crops, exporting less than 22% of domestic output (Table 13.2). At the same time, North America accounts for one-third of world trade in crops. The region thus faces inelastic demand for crops. In this case, technical progress in agriculture generates an "output price treadmill" (Cochrane 1958; Hayami and Ruttan 1985; de Janvry 1973). Crop prices fall more than crop output increases (Table 13.2, column 2). Revenues fall by a greater percentage than costs. The prices of land in both crop and livestock production fall. Land use is shifted out of crop production toward livestock. Labor is released from crop production and moves to other sectors. Consumer prices of food fall, and wages rise relative to the prices of purchased commodities.

Technological progress in agriculture *relative to industry* supplies more output to other sectors and "frees" labor for nonagricultural production. Owen (1966) has referred to this release of output and labor as "the double development squeeze on agriculture" and has referred to technical change in agriculture as a "dynamic intersectoral concealed and cumulative tax on agriculture" (p. 56). The decline in agricultural returns is not a result specific to the AGE framework. Rather, it has to do with the nature of the supply curve shift in the presence of inelastic demand.[7]

Technological change in North America has significant welfare implications for producers and consumers in other regions. The composite price index for land falls 0.60% in North America, and between 0.47% and 0.82% in other regions (Table 13.4). Domestic and foreign consumers are the main beneficiaries of technical change in North American crop production. World welfare increases by over $4.5 billion, but North America receives less than $2.6 billion of this total. Crop sector employment declines about half a percent across all regions. East Asia and the European Union (EU), two net crop importing regions, are both major beneficiaries of technical change in North America; however, welfare in Australasia, a crop exporter, declines.

Southeast Asia. Southeast Asia produces crops primarily for domestic consumption and faces inelastic demand for crops (Table 13.2). Food and agriculture account for a large share of employment and consumption compared to the other two regions. These two features result in a distinctly different outcome when crop productivity grows in this region. Specifically, a 2% growth rate increases global welfare by over $1.2 billion, with 75% of this welfare gain captured domestically. The major foreign beneficiaries in terms of equivalent variation (EV) are East Asia and the EU (Table 13.4); Australia and ROW sustain net welfare losses. The composite land price and crop sector employment fall in all regions. In Australasia and North America, these decreases are as big as in Southeast Asia itself. Domestically, crop price falls more than output expands. Labor and land shift out of crop production, and the value of land in crops falls.

Falling crop prices stimulate livestock and processed food production to a much larger extent than the other regions, with food production increasing 0.9%. In the livestock sector, both revenues and land values increase. Labor is pulled from crop and manufacturing sectors toward food and livestock production.

Technical change in crops also has a much larger positive impact on wage rates than in the other regions. Increased crop productivity raises the ratio of the wage rate to the price of processed food by 0.77%. The increase in the wage–food price ratio has important implications for the rural poor. Lower food prices have been argued to redistribute income to poor households effectively because those households spend a relatively large proportion (60–80%) of their income on food (De Franco and Godoy 1993; Lipton and Longhurst 1985; Pinstrup-Anderson 1987). Private household consumption of processed food, and manufactures and services all increases by about 0.4%.[8]

In developing countries the impact of technological change on rural households is complex. First, returns to land holders depend on what type of land they own. Average land values fall, but this average change masks differential returns to different types of land. The price of cropland *declines* by 0.34%, and the price of pasture land *rises* by 0.29%. Rising crop productivity redistributes producer surplus from owners of cropland to owners of pastureland.

Second, smaller-scale, "semisubsistence" producers in developing countries are often net suppliers of agricultural labor, net purchasers of food, and tenants rather than land owners (Hayami and Ruttan 1985; de Janvry and Sadoulet 1987; Renkow 1994). The GTAP model does not disaggregate by household type, yet the aggregate results have interesting implications for poorer rural households. The value of owned cropland and its rental price declines, and the wage–food price ratio appreciates. The results suggest that crop productivity growth can have progressive impacts on rural incomes.[9]

The case of Southeast Asia highlights how general equilibrium analysis provides results quite different from those derived from partial equilibrium analysis. Single-commodity analysis would miss the important stimulus increased crop productivity provides to the livestock and processed food sectors. It would also miss the fairly significant impacts of increased wages and growth in household consumption of nonagricultural products.

Experiment 2: Effects of technological spillovers

This experiment (E2) considers a case in which research not only reduces costs in the innovating country, but also leads to spillovers that reduce costs in other regions. An increase in the technology augmentation parameter of 2% is equivalent to a downward shift of the unit cost function by 2%, all else equal. In E2 it is assumed that research carried out in one region reduces costs in all regions by 2%. In the terminology of Edwards and Freebairn (1984), the ratio of domestic to ROW cost reduction is 1. This is the simulation strategy employed by those authors.[10]

Alternatively, one may think of the 2% global crop productivity increase as the sum effect of all research activities. Thus, the example considers a worldwide increase in crop productivity *relative to other sectors.* The shock applied to the GTAP model is a 2% increase in the output augmentation parameter, *ao*, for the crops sectors of all six regions simultaneously. The results of global technological progress in crop production are presented in Table 13.3, columns 4–6 and in Table 13.4, column 4.

The impacts of agricultural technological progress on a global scale differ from single-country impacts in a number of important respects. Revenues for both crops and livestock fall in all regions. The movement of resources out of crop production and all agricultural sectors is more pronounced. Land shifts more toward livestock production than in E1. Labor moves out of both livestock and crop sectors in all cases. The presence of spillovers constrains domestic output expansion and makes the fall in food and agricultural prices more pronounced. Spillovers in crop research also make both domestic and foreign land holders worse off. Land in crops falls by more than 3% in the focus regions, and the price of land in livestock falls by more than 1.8% (Table 13.3). The composite price of land falls between 2.4% and 3.6% across regions (Table 13.4).

Spillovers also shift the *relative* gains of technical progress away from the innovating region and toward technology borrowing regions. Spillovers decrease *absolute* welfare gains (EV) in Australasia by over $38 million and in Southeast Asia by $886 million (Table 13.3). In North America, spillover effects actually increase EV by $744.57 million, even though returns to the farm sector decline.

Experiment E2 suggests that the major beneficiaries of pervasive increases in crop productivity are consumers in ROW followed by those in East Asia and the EU. E2 also illustrates the output price treadmill and Owen's (1966) "double development squeeze" operating on a global scale. This also highlights the dilemma of the international agricultural research system created by its very success. Agricultural productivity growth historically has been higher than in other sectors. When this occurs on a global scale, returns to agricultural asset holders decline, labor and capital move out of agriculture, and the world economy becomes less agricultural. As Timmer (1988) notes, "Technical change is also a major factor explaining the rapidly falling share of national income captured by agriculture directly" (p. 297).

E2 also has implications for standard evaluations of the international agricultural system as a whole. Such evaluations tend to survey partial equilibrium studies of impacts of research in a single commodity that suggest innovation in a single commodity increases producer surplus and draws resources into production of that commodity. E2 demonstrates that it is not valid to treat the global impacts of agricultural research as simply the sum of individual-country or -commodity impacts. When agricultural productivity grows relative to nonagriculture on a global scale, producer surplus falls and resources move out of agriculture.

Experiment 3: Falling behind technologically

This experiment (E3) consists of three simulations: a 2% output augmenting technical change in the crops sector of all regions except (1) Australasia, (2) North America, and (3) Southeast Asia, respectively. Here, each of the three cases in E3 is compared with E2 to examine what happens when a region does not keep up with others technologically.

Australasia. When Australasia keeps pace (E2) with other regions, crop output increases. When other regions increase their relative productivity, however, the region's crop, livestock, and food sectors all contract. Factor prices fall more than in E2, but output prices (particularly crop prices) fall less. Domestic crop prices fall by 1.8% in E1, by 2.8% in E2, but by only 1.0% in E3. This last result may seem counterintuitive. Wouldn't productivity increases in all regions except Australasia have more of an impact on domestic crop prices than a productivity increase in Australasia alone? If domestic and imported crops were perfect substitutes this would be true. However, the Armington assumption implies that imported and domestic crops are imperfect substitutes. Therefore, the associated prices are differentially affected by these two shocks.

When other regions improve their crop productivity relative to Australasia there are a number of negative economy-wide impacts. Domestic equivalent variation actually declines by $157 million. The wage rate also declines relative to the prices of manufactures and services, which account for a large percent of private household consumption.

North America. Some impacts of North America falling behind in crop productivity are similar to those in Australasia. Sectoral output and employment contract for crops, livestock, and food. Domestic equivalent variation (EV), although positive, is about $2.5 billion less than E2. Global welfare is over $5 billion less. Wages and capital rental rates fall more and food prices fall less when the region doesn't keep pace. More specifically, failure of the North American crop sector to keep pace technologically reduces returns to domestic labor and capital, reduces global welfare, and leads to relatively higher food prices. These negative consequences are external to agricultural producers, however.

The experiment provides some paradoxical results with respect to agriculture. Returns to agricultural land owners are actually higher when North American crop productivity is stagnant relative to its competitors. Also, in the North American case, more labor moves out of crop and livestock sectors in E2 than in E3. One reason for these results is the large influence North America has on the world crop prices. Additional North American output exerts a strong downward pressure on agricultural prices, revenues, and land rents.[11]

Do these results mean that stagnant productivity is good for North American farmers? Before rushing to this disturbing conclusion, a number of caveats need mentioning. First, assumptions about the Armington elasticities strongly influence overall crop price elasticities. Further sensitivity analysis is needed to test robustness of results to assumptions of import and domestic good heterogeneity. We know, for example, that the long-run elasticities will be larger, thereby increasing the chances of a decline in returns. Second, the simulations assumed that the power of subsidies to crop producers is constant. In many actual commodity programs, such as target price–deficiency payment schemes, the power of the subsidy increases endogenously to maintain producer prices.[12] Third, rural households supply labor that earns a relatively higher wage, and they purchase food that can be obtained more cheaply. Fourth, the demand elasticity for individual crops will be higher than for the aggregate crop sector.

Southeast Asia. When Southeast Asia falls behind technologically in crop production, wage rates fall relative to prices for manufactures and services. Domestic welfare declines by over $57 billion relative to a base of no technological change (i.e., compared to E1). Domestic welfare falls by over $940 million compared to the case of keeping pace technologically (i.e., compared to E2). As was the case with Australasia, domestic prices for crops and livestock decline more when the home region reduces costs of crop production than when all other regions reduce their costs.

V Impacts of food processing research

This section considers three simulations meant to examine technological competition in food processing:

- E4a: a 1% cost reduction in the North American processed food sector
- E4b: a 1% cost reduction in the processed food sector of all regions
- E4c: a 1% cost reduction in the processed food sector of all regions except North America

Based on estimates from the Bureau of Labor Statistics, the long-run annual rate of cost diminution in the US food processing sector has been about 0.6% per year since the Second World War. Thus, the 1% cost reduction in this experiment is larger than the long-run average annual rate of technological change. Technical change in the food sector has been primarily labor

Table 13.5. ***Impacts of Research that Reduces Costs of Processed Food Production (cost reduction achieved through labor augmenting technical change)***

Percent Cost Reduction in North America in Other regions	E4a 1% 0% (1)	E4b 1% 1% (2)	E4c 0% 1% (3)
Output[a] (*qo*)			
Crops	0.25	0.22	-0.03
Livestock	0.56	0.21	-0.34
Food	0.60	0.21	-0.38
Output Prices(*pm*)			
Crops	0.09	0.05	-0.03
Livestock	-0.17	-0.22	-0.04
Food	-1.05	-1.09	-0.04
Manufacturing	0.03	0.01	-0.02
Services	0.02	0.00	-0.02
Factor Prices (*pfe*)			
Land in crops	0.70	0.50	-0.19
Land in livestock	0.92	0.50	-0.40
Labor	0.05	0.03	-0.01
Capital	0.02	0.00	-0.02
Employment (*qfe*)			
Crops	0.32	0.26	-0.05
Livestock	0.65	0.26	-0.38
Food	-2.43	-2.81	-0.38
Industry Demand (*qf*)			
For crops by livestock sector	0.56	0.21	-0.34
For crops by food sector	0.60	0.21	-0.38
For livestock by food sector	0.60	0.21	-0.38
Equivalent Variation (*EV*)			
Domestic ($US billions)	4.99	5.08	0.11
Total ($US billions)	5.11	27.55	22.47

[a] All impacts are on North America unless otherwise stated.
[b] All impacts expressed in terms of percentage change except for equivalent variation.

augmenting (Lee 1986; Connor 1988). In this experiment Harrod-neutral technical change (Chambers 1988) is assumed to reduce costs by 1%.[13] The 1% cost reduction was achieved by shocking the labor augmentation parameter *afe* by 1% divided by labor's cost share in the food sector of a region. Table 13.5 shows the impacts of a 1% cost reduction in the food sector from labor augmenting technical change.

The model assumes that the elasticity of substitution between farm products (crops, livestock) and other inputs is zero in the production of processed food (although any user with access to GEMPACK could easily alter this assumption). Previous studies using multistage production models have shown that the distribution of gains from food processing research between processors, consumers and farmers is sensitive to this assumption (Alston and Scobie 1983; Holloway 1991; Mullen, Wohlgenant, and Farris 1988; Mullen, Alston, and Wohlgenant 1989). Assuming fixed proportions can overstate the benefits to farmers of certain types of processing research.

There are a number of reasons why assuming fixed proportions between farm and other inputs may not be too unreasonable. First, as Freebairn, Davis, and Edwards (1983) note, there is little in the way of econometric evidence to suggest that this elasticity differs much from zero. Second, multistage models make a number of simplifying assumptions that also affect the direction and distribution of welfare impacts that are less empirically or theoretically defensible than the fixed-proportions assumption.[14] The GTAP model is not restricted to using these other assumptions. Third, a main result of sensitivity analysis regarding the substitutability of farm products and other inputs in food processing is that farmers need not benefit from certain types of processing research. As will be shown below, the GTAP model also yields this basic result.

Technological change in North American food processing with no spillovers

When North America is the sole innovator in processed food, then domestic food, crop, and livestock sectors all expand. Land values rise, and employment increases in the crops and livestock sectors. Labor saving technical change reduces employment in food processing by 2.4%. However, wage rates rise relative to prices of purchased commodities.

The size and distribution of research gains depend crucially on the stage of production where technical change occurs. A 2% cost reduction in North American crop production yields a domestic welfare increase of $2.58 billion and a world welfare increase of $4.55 billion (Table 13.4). About 57% of the welfare gain is captured domestically. In contrast, a 1% cost reduction in North American food production yields a domestic welfare increase of $5 billion and world welfare increase of $5.1 billion, with 98% of the welfare gain captured domestically. Increased crop productivity reduced returns to agricultural land holders, and increased food productivity increased these returns.

A 1% cost reduction in North American food production through labor augmenting technological change appears superior to a 2% cost reduction in North American crop production according to a number of criteria: (1) domestic welfare improvement, (2) global welfare improvement, (3) domestic capture of welfare gains, (4) returns to agricultural producers, (5) maintaining agricultural employment, and (6) raising the ratio of the wage rate to the price of food. Criterion (6) has distributional implications as the poor spend relatively more of their incomes on food.

Three points should be kept in mind, however. First, the comparison is between *gross* benefits of productivity increases. It says nothing about the difficulty or *cost* of achieving those increases. The postwar rate of productivity growth in food processing has been a third of that for crop production. A complete accounting of the relative benefits of each type of research is beyond the scope of this chapter (it would require estimation of the net present value of the research costs needed to achieve such productivity gains). Second, the type of technical change in food processing matters. Agricultural land holders benefit from labor augmenting technical change in food processing, but would not necessarily benefit from other types of change.[15]

The third issue has to do with technological spillovers. Spillovers from crop research could be much lower than those in food processing. Crop breeding research is often tailored to particular agro-climatic conditions. In food processing, mechanical innovations can be readily spread through technology transfer and through expansion of multinational firms. A more accurate comparison of benefits of productivity increases might be argued to be between crop productivity growth with no (or little) spillovers greater than the gross benefits of food research with significant spillovers. We turn now to this comparison.

Technological spillovers in food processing

The impact of research that reduces unit costs of food production by 1% in North America and all other regions (E4b) is presented in column 2 of Table 13.5. Compared to the case with no spillovers (E4a): (1) North American crop, livestock, and food outputs expand less, (2) agricultural land rents and employment increase less, (3) employment in food processing declines more, (4) domestic food prices fall more, (5) domestic welfare is 3% greater, (6) world welfare is more than five times greater.

Research that reduces food processing costs 1% in all regions yields domestic welfare benefits that are nearly double those obtained from a cost reduction of 2% in crop production. Domestic EV is $5.1 billion in the former case and $2.7 billion in the latter. Global EV increases by $27 billion, with a 1% reduction in food production costs in all regions; it increases by $23 billion with a 2% cost reduction in crop production in all regions.

Spillovers in food processing to other regions reduce gains to land holders relative to what they would otherwise be. However, returns to North American land holders still increase in case E4c, and they decline with cost reductions in North American crop production. Spillovers in processing have a positive impact on overall North American welfare, even though they lessen farm sector benefits.

Falling behind technologically in food processing

When North America falls behind technologically (E4c = Table 13.5, column 3), domestic production of crops, livestock, and food falls. Land values also fall, and labor moves out of agriculture and food processing. The gross cost of falling behind technologically in the food sector can be measured by comparing the difference in EV between cases E4b (North America keeps pace) with case E4c (all regions but North America reduce costs by 1%). When other regions reduce their costs relative to North America, the cost of falling behind is $5 billion in forgone domestic welfare. In contrast, when other regions reduce their costs of crop production by 2% relative to North America, the cost of falling behind is less than $2.6 billion.

There has been much discussion in the popular press about the need to maintain "competitiveness" as a means of preserving domestic jobs in particular sectors. Column 3 of Table 13.5 shows the case where North America has fallen behind technologically and employment in the food sector declines 0.4%. Keeping pace technologically translates into higher sectoral output but does not translate into higher sectoral employment. When domestic technology keeps pace with foreign competition (column 2, Table 13.5), wages in the whole economy and overall welfare are higher, but employment in food processing declines by 2.8%.

VI Biased technological change

AGE studies frequently model technical change as output augmenting and factor-neutral. Table 13.6 compares the effects of a 1% cost reduction in the North American food sector from technical change that is (E4a) labor augmenting, (E5) neutral/output augmenting, (E6) livestock augmenting, and (E7) services augmenting. For factor-biased technical change, the size of the shock was adjusted by the factor cost share to achieve equal rates of cost diminution for each of the experiments.

These experiments seek to demonstrate two points. First, the assumption of factor neutrality in technical change often made in AGE model experiments is not an innocuous one. Prices, sectoral employment, and returns to primary factor owners are sensitive to assumptions about the bias of technical change.[16] Second, increased technological efficiency in the food processing sector may not generate benefits at the farm level.

The effects of labor augmenting technical change were discussed in the previous experiment. Output augmenting technical change leads to a reduction in agricultural (crop, livestock) production and employment and a decline in land values. Livestock augmenting technical change has these same effects but the magnitude is much greater, particularly in the livestock sector. Employment in that sector falls 4.5% and the land price falls 4.8%. The demand for livestock by the food sector declines 4.7%. This has feedback effects to the crops sector, where demand for crops by the livestock sector declines by 3.9%. Increased productivity in the processing sector does not necessarily generate benefits at the farm level and can actually create welfare losses. This has fall, and labor moves out of agriculture and food processing. The gross cost of falling behind technologically in the food sector can be measured by comparing the difference in EV between cases E4b (North America keeps pace) with case E4c (all regions but North America reduce costs by 1%). When other regions reduce their costs relative to North America, the cost of falling behind is \$5 billion in forgone domestic welfare. In contrast, when other regions reduce their costs of crop production by 2% relative to North America, the cost of falling behind is less than \$2.6 billion.

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First, multimarket effects of technological change in a single region for a single commodity were quite substantial. Foreign welfare gains from domestic cost reductions in crop production ranged from 32% to 92% of domestic gains, depending on the country. Crop cost reductions in a given region reduced agricultural land values in all other regions. Percentage changes in foreign land values were comparable and sometimes larger than changes in the innovating region.

Second, domestic impacts of technological change depend on the importance of crops in trade and the importance of crop production in the region's overall economy. Australia, a small exporting country, faces elastic demand for crops. Cost reductions in crop production increased land values and pulled resources into agriculture. North America, a large exporter, and Southeast Asia, producing primarily for domestic consumption, face inelastic demand for crops. Crop cost reductions in these regions caused agricultural land values and employment to decline. In Southeast Asia, where agriculture accounts for a larger share of employment and consumption expenditures, technological change in crop production generated important general equilibrium effects. A 2% reduction in the unit cost of crop production caused the wage–food price ratio to rise and increased private household consumption of food and manufactures and services.

The chapter examined technological spillovers following the approach of Edwards and Freebairn (1984) which assumes that cost reducing innovations in one region can be adopted by other regions. The simulations illustrated that when all other regions could reduce costs by as much as the innovating region: (1) global welfare rose more than 10 times over single-region cost reductions, (2) relative research benefits shifted away from the innovating region and toward other regions, (3) net research gains shifted from crop producers to consumers, and (4) agricultural land values decline in all regions. Also, spillovers reduced aggregate domestic welfare gains (relative to the no-spillover case) in Australasia and Southeast Asia but increased gains in North America.

Fourth, the impacts of agricultural research as a whole are quite different from the impacts of isolated changes in a single region. When global agricultural productivity grows relative to other sectors, land values fall and agricultural employment declines. Major beneficiaries of agricultural productivity growth on a global scale are consumers in the EU, East Asia, and ROW.

Fifth, the gross benefits of cost reductions in food processing are substantially larger than those for cost reductions in crop production. A 1% cost reduction in the North American food processing sector yielded $5.0 ($5.1) billion in domestic (world) welfare benefits; a 2% reduction in the North American crops sector yielded \$2.6 (\$4.5) billion in domestic (world) welfare benefits.[17] The costs to North America of falling behind technologically in food processing were also substantially larger than the costs of falling behind in crop production.[18] These results give cause to reiterate the point made by Freebairn, Davis, and Edwards (1982) that greater attention to research and productivity growth beyond the farm gate is warranted.

Sixth, keeping pace technologically with international competition does not necessarily maintain employment in a sector. Two cases compared what happened to domestic sectoral employment when rates of technical change varied across regions. In the first case, all regions but the home region experienced cost reductions. In the second, all regions including the home region experienced the same percentage cost reductions in a sector. In the North American and Southeast Asian crops and North American processed food sectors, more labor left those sectors when they kept pace technologically than when they did not. For the crop sectors this was due in part to the inelastic demand those sectors faced. For processed food, technological change was assumed to be labor-saving in keeping with empirical evidence (Connor 1988).

Finally, the distribution and size of returns from research were sensitive to the factor bias of technical change. Crop and livestock producers do not necessarily gain from all types of cost reductions at the food processing level. Agricultural land holders benefited from labor and services augmenting technical change, but were negatively affected by output and livestock augmenting technical change. Services augmenting technological change achieved multiple goals of raising agricultural prices and land values and increasing employment in food and agriculture sectors. However, a 1% unit cost reduction from services augmenting technological change yielded lower overall welfare gains (EV) (10% less) than equal cost reductions from other types of technical change.

The simulations presented in this chapter are meant as a pedagogical device to demonstrate potential applications of AGE models to the analysis of the size and distribution of returns to agricultural research. AGE models have been widely applied to evaluate the impacts of trade policies, tax policies, and development strategies. Technological change has generally been examined only incidentally in such studies.[19] Analyses of returns to agricultural research have increasingly recognized the importance of extending analyses of multimarket effects vertically (up and down the production chain) and horizontally (across both commodities and regions). One goal of this chapter is to present AGE models as a logical and coherent extension of these multimarket analyses.

This does *not* mean that AGE analysis of technological change is "better" than partial equilibrium analysis. Partial equilibrium studies have several advantages, which include greater ease in modeling sectoral details more explicitly, employing more flexible functional relationships, and bringing larger amounts of econometric evidence to bear on particular parametric specifications. Nevertheless, AGE models remain a little exploited tool in our tool kit to evaluate impacts of agricultural research.

The relatively general experiments presented in this chapter are meant to demonstrate the breadth of issues that may be examined in the GTAP framework. It would be interesting to pursue more precise policy analyses as extensions of this chapter. Two possibilities follow.

1. *Measurement of a general equilibrium net present value of research investment.* The current GTAP model is calibrated to 1992 world economic data. The model could be used to compute the gross research benefits from multifactor productivity growth in crop and livestock sectors from 1991 to 1992 levels attributable to research. One could then use econometric estimates of productivity-research relationships to impute a cost of achieving that level of productivity growth. Results of research costs and benefits could then be used to calculate the net present value of research investment.
2. *Evaluation of changes in agricultural price support and trade regimes on the size and distribution of research benefits.* The current model includes extensive information about subsidies and tariffs in agriculture (and other sectors). Alston, Edwards, and Freebairn (1988); Murphy, Furtan, and Schmitz (1993); Frisvold (1991), and Oehmke (1988) have discussed the theoretical implications of trade barriers and other market distortions on research gains. The model can be employed to examine how returns to research are affected by changes in trade and policy regimes. For example, how might the Uruguay Round Agreement, discussed elsewhere in this volume, affect the returns to different types of research in different regions? Of particular importance is the tariffication of nontariff barriers, which have hitherto inhibited the global transmission of price signals engendered by technological change.

In sum, the analysis of technological change using the GTAP framework is a fruitful area for future research.

NOTES

1. Important exceptions are White and Araji (1991) and Martin and Alston (1994), which use models of two horizontally linked commodities to examine multimarket effects of research.
2. An exception is Mullen, Alston, and Wohlgenant (1989).

3. Davis (1991) cites the case of forestry research for hot subtropical desert environments, conducted in Australia. Such research is only narrowly applicable across Australian production environments but applies to "a large share of Egypt's production."
4. This result does not necessarily hold in the model presented in this chapter.
5. Log-linear models (Akino and Hayami 1995, Scobie and Posada 1978) assume supply curves pass through the origin of the price–quantity axis. This implies an underlying technology with no shutdown point for firms at any positive output price. Models with inelastic, linear supply functions imply that positive amounts of output would be supplied at nonpositive prices.
6. Schmitz and Seckler (1970) and Brandt and French (1983) do focus on employment effects.
7. For discussion of theoretical conditions and empirical examples of producers losing from technological change, see Duncan and Tisdell (1971), Lindner and Jarrett (1978), Rose (1980), Scobie and Posada (1978), and Wise and Fell (1980).
8. Domestic crop productivity growth increased private household demand for these commodities by about one-fourth as much in Australasia and North America.
9. Both de Janvry and Sadoulet (1987) and Renkow (1994) find such impacts from agricultural productivity growth in models with more disaggregation by household type.
10. Edwards and Freebairn (1984) considered a range of spillover ratios. Davis (1991) notes that interregional spillover rates can exceed unity.
11. Recall that a 2% cost reduction in North American crop production led to a 0.4% reduction in world crop prices (Table 13.4, column 2).
12. An interesting experiment would be to examine the effects of a target price–deficiency payment scheme on the size and distribution of gains and losses from technological change.
13. Harrod-neutral technical change increases the efficiency of labor inputs but leaves the efficiency of other inputs unchanged (Chambers 1988).
14. These include assumptions of (1) linearity of demand and supply functions, (2) supply functions that cut the quantity axis, and (3) parallel supply curve shifts.
15. This point is discussed in more detail in section VI.
16. Coxhead and Warr (1991) examine effects of different types of factor bias using an AGE model of the Philippines. Godoy et al. (1993) compare effects of output augmenting for food versus export commodities in Bolivian AGE.
17. Figures for gains from food research assume labor augmenting technical. However, considering other types of technological change did not alter this qualitative result.
18. The experiments to generate these results assumed that all other regions but North America experienced cost reductions of 2% for crops and 1% for food, respectively.
19. Two interesting exceptions are papers by De Franco and Godoy (1993) and Coxhead and Warr (1991).

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