

# Appendix

## Effects of Economic Growth in Developing Countries on U.S. Agriculture: Preliminary Evidence from a Global Computable General Equilibrium (CGE) Model

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### Introduction

In an environment of slow advances in the multilateral agricultural trade negotiations, and with the current suspension of the WTO Doha Round negotiations, a continuous issue for U.S. agriculture is building export market opportunities for its products. While the largest share of U.S. trade is with other industrial countries, growth in developing countries may open new agricultural export opportunities. At the same time, growth among large agricultural producers, such as Brazil (a major exporter) or India (largely self-sufficient but with a huge rural population and increasing trade), may create competition for U.S. agriculture.

The argument that income growth abroad among low-income countries benefits U.S. agriculture has a long tradition. This argument has underlain support within large segments of agriculture for more open trade, as well as support for food aid and other foreign assistance programs aimed at generating foreign growth. The increased U.S. agricultural exports to several developed Asian countries, such as Japan, South Korea and Taiwan as they emerged from relative poverty in the 1950s-1960s to high-incomes by the 1980s-1990s, is often cited to demonstrate the positive growth effects. Driven by rising incomes, U.S. agricultural exports have increased to these countries simultaneously with substantial increases in their own domestic agricultural production and despite significant trade barriers.<sup>2</sup>

On the more cautious side, U.S. agricultural producers recognize that they face stiff competition in international markets. Growth in soybean production in Brazil as new technologies were developed is cited to illustrate the dynamic character of “comparative advantage” of countries as international sources of the world food supply. Agricultural interest group concerns over promoting production abroad have led to some restrictions on U.S. foreign aid programs.

This report presents estimates of the effects that increased GDP growth in selected developing countries would have on U.S. agricultural production and trade. The results are obtained from simulations using the MIRAGE (Modeling International Relationships in Applied General Equilibrium) global model.<sup>3</sup> There are substantial increases in export to the affected countries when GDP growth rates from 2007 to 2020 are simulated to increase to 7% per year. This level of GDP growth is within the range achieved by such fast-growth economies as China and recently India, but is a sharp increase from past growth rates among most poor countries. It also exceeds the future GDP growth rates projected by the World Bank (2006) for the countries considered.

With the simulated higher growth, our results suggest there is also a small positive effect at the aggregate level of U.S. production and trade.<sup>4</sup> The aggregate effects are smaller than the effects on exports to the regions assumed to experience higher growth because the countries for which we simulate increased growth represent only about 13 % of the U.S. agricultural trade volume. Gains are larger when we manipulate the model to partially mimic the shift toward lower shares of GDP in agriculture that has occurred historically in fast-growing countries.<sup>5</sup> Gains to U.S. agriculture depend also on the composition of countries where GDP growth occurs. Faster growth among net agricultural importers generates positive gains, while growth in developing countries that are large net agricultural exporters impact negatively on U.S. agriculture.

The model and results are discussed below. We note at the outset the preliminary nature of our analysis to date. This modeling exercise has opened many interesting research questions that merit further exploration before definitive conclusions are drawn.

## Model Specification for the Growth Simulations

MIRAGE is a multi-region, multi-sector global computable general equilibrium (CGE) model. For the purposes of evaluating the effects of higher GDP growth rates, two important features are:

- The model has a sequential dynamic set-up from 2002 to 2020. In our analysis, exogenous changes to GDP growth rates are introduced and model simulation outcomes are compared with the results obtained from the “baseline” projections before the changes. Elements of MIRAGE that reflect its dynamic modeling capacity include investment, land supply, share of skilled and unskilled labor, economies of scale, and the emergence or closure of firms in certain sectors.<sup>6</sup> In our analysis, the model adjusts to the higher simulated growth rates by finding corresponding rates of total factor productivity (TFP), an endogenous variable that given other model outcomes is determined so that the economy replicates the assumed growth rate levels.
- CGE models require a “macroeconomic closure” rule. In MIRAGE, the macroeconomic closure assumes that the current account of each country/region is constant and equal to its initial value. To accomplish this, the real exchange rate is allowed to adjust to balance the current-account equation. Consequently, when forces stimulating exports arise, such as increased income growth abroad, they are partly offset by appreciation of the currency to retain current-account balance.

## Growth Simulations

For the purpose of this analysis, the MIRAGE model is structured around 10 country/regional groups of various income levels, as shown in Table 1. The model includes 20 productive sectors, of which 11 are in agriculture (agro-food), as shown in Table 2.

In the baseline we generate with the MIRAGE model over the period 2002-2020, the GDP growth rates for the countries and regions are those forecasted by the World Bank (2006).<sup>7</sup> In the main simulation presented, the GDP growth rates in four selected regions are raised to 7% during the period 2007-2020. The selected regions include four developing-country groups that are net importers of agricultural products:

1. the low income African country-group (ldcf),
2. the middle income African country-group (micf)

3. the low income Asian country-group (ldcs)
4. the rest of the world (rotw), which is a mixture of low and middle income countries.

The simulated GDP growth rates represent a sizeable increase from the baseline. The World Bank (2006) forecasts over the period 2007-2020 are for GDP growth rates averaging 3.53% for low income Africa (ldcf); 3.76% for middle income Africa (micf), 3.66% for our rest of world (rotw); and 5.07% for low income Asia (ldcs).

In the baseline, TFP rises equally in all sectors to replicate the projected growth rates. For this reason, the shares of GDP from different sectors remain largely unchanged. In contrast, as noted above, the historical experience of fast-growing economies has been a shift toward relatively less GDP from agriculture and more from industry and services.

To introduce an effect along lines of the shifting shares of GDP from agriculture versus other sectors as rapid growth occurs, our main simulation makes the assumption that TFP growth in agriculture occurs at a declining rate compared to non-agriculture. After the basic results are presented, several other scenarios are briefly evaluated for comparative purposes.

## Results

The four selected regions account for 7.7% of world GDP and 17% of world agricultural production in 2005.<sup>8</sup> Aggregate effects of faster GDP growth on U.S. agricultural production, exports and imports are shown in Table 3 as percentage changes from the baseline in 2020, the last year of the simulation period. In aggregate, the volume of U.S. production among the agro-food sectors is higher by 0.32%, while export and import volumes are 2.88% and 1.74% higher, respectively. Growth of total U.S. agricultural production, exports and imports from 2007 to 2020 are projected in the benchmark to be 54.40%, 89.35% and 33.99%, respectively, without the simulated faster growth of GDP among the selected developing-country regions.

In terms of specific agricultural products and sub-sectors, production of wheat, other cereals and rice register the highest gains (3.06%, 2.43% and 1.92%, respectively). Exports of other cereals increase by 8.05%, followed by rice (7.12%) and wheat (4.59%). Oilseeds, meat and meat products, fruits and vegetables, food products, and other agriculture are other sectors that show gains in export volumes, although this last sector's production declines. Sugar and plant based fibers show lower

production and export volumes, while milk production increases slightly but exports decline.

Faster growth among the four regions also increases U.S. agricultural imports. In part this arises due to increased foreign supplies, and in part it reflects the real appreciation caused by expanded demand for U.S. exports and the constraint that the current account remains constant. Agricultural imports increase less in aggregate than exports, but imports increase in all sub-sectors, with the highest gains in plant-based fibers, rice, sugar and other agriculture.

The effects of higher GDP growth on the agricultural exports from the United States are shown by region and product in Table 4. For each product, the first row shows the percentage increase of U.S. exports in 2020 under the fast-growth simulation compared to the baseline. The second row shows the percentage of total U.S. exports of each product going to each region.

For the specified regions, the gains for U.S. exports from increased growth are significant. In 30 of 44 cases, they exceed 20% and are as high as 46.61% (other cereals exports to rotw). Overall, the largest percentage gains are for exports to middle income Africa and the rest of world regions (micf and rotw). The percentage gains are lower for the low-income regions, particularly for Asia (ldcs). Among products, percentage gains in exports to the regions are greatest for cereals (rice, wheat and other cereals), oilseeds, and fruits and vegetables. A few illustrative results are:

- Exports of rice to low income Africa (ldcf) represent 7.94% of U.S. rice exports and rise 26.43%. Rice exports to rotw represent another 16.95% of the total and increase by 27.76%.
- Wheat exports to middle income Africa (micf) represent 18.04% of total U.S. exports and increase by 17.73%. Wheat exports to rotw represent 10.1% of the total and increase by 25.96%.
- Other cereal exports to middle income Africa (micf) represent 11.86% of the total and increase 40.7%.
- Exports of oilseeds and fruits and vegetables increase by more than 19% to both the Africa and Asia low income regions (ldcf and ldcs) and by more than 30% to middle income Africa (micf), but the proportion of total U.S. exports of these products to each of these regions is less than 2%. Exports of oilseeds and fruits and vegetables to rotw represent 3–4% of the total and also increase by more than 30%.
- Exports of the remaining products to the low income Africa and Asia regions (ldcf and ldcs) and

middle income Africa (micf) each represent less than 4% (and often less than 1%) of the total U.S. exports. Percentage increases are often large, but from the very small baseline levels.

## Alternative scenarios

To provide some context around these preliminary results about the effect of faster GDP growth among low-income and middle-income net food importing countries, we evaluated several alternative scenarios. The aggregate result for U.S. agricultural production, exports and imports are shown in Table 5 for five cases.

In the first and second alternative cases, simulating less increase in GDP growth rates in developing regions leads to smaller effects. Setting GDP growth rates to a minimum of 4% in ldcf and micf has almost no effects, while there are gains to production, exports and imports of 0.12%, 1.03% and 0.66%, respectively, when the minimum growth rate is 5% in ldcf, micf and rotw. In the third alternative, the growth in agricultural TFP is made equal that of non-agriculture sectors resulting in lower gains to U.S. agricultural production and exports, and increased U.S. agricultural imports, relative to the main simulation. U.S. agricultural production increases by only 0.19%, while U.S. agricultural exports increase by only 1.75%.

In the fourth alternative, we also simulate a 7% GDP growth in the Latin American region (amla) that includes large agricultural producers and exporters, as well as in the four initial regions (an increase from growth rates forecast to average 3.54%). The net results, even with slower TFP growth in agriculture than non-agriculture, are small losses to the U.S. agricultural production and exports, with an increase of agricultural imports.

Finally, we consider a “slower growth” rather than “faster growth” scenario. Specifically, we reduce the growth rate for the middle income Asia region (mics), which includes China, India and other high-growth performers. The GDP growth rates for the middle income Asia region is reduced from World Bank (2006) projected levels averaging 5.68% to just 3%. This change in isolation (no change from baseline growth rates for any other region and with equal TFP growth declines for agriculture and other sectors), results in a decline of U.S. agricultural production by -0.29%, a decline of agricultural exports by -4.12% and a decline of agricultural imports by -2.01%. As with our main simulation results, these alternative effects for a simulated growth slow-down for the recently fast-growing regions of Asia demonstrate that GDP growth abroad can have a beneficial effect on U.S. agriculture.

## Conclusion

GDP growth in developing countries may generate gains for U.S. agriculture. We have examined these effects by simulating increased GDP growth in selected developing regions using the MIRAGE model. In our analysis, U.S. agriculture benefits from increased demand generated by higher income when these regions are net agricultural importers. We find that an ambitious growth rate of 7% in the selected developing countries with lower productivity growth in agriculture than in non-agriculture to reflect changes in sectoral composition as growth occurs generates gains to U.S. agricultural production and exports, as well as leading to increased U.S. agricultural imports. Gains also arise from the rapid recent growth among middle income Asian countries. A slow down of this rapid growth is shown to have deleterious effects. U.S. agriculture can also face increased competition from growth abroad among strong agricultural exporters, such as in Latin America.

The results we have presented are suggestive but preliminary. The research has raised interesting questions about growth and its effects and about adopting global CGE models such as MIRAGE to evaluate these effects. These questions merit further investigation before definitive conclusions are drawn about the effects of increased growth rates among low and middle income countries on U.S. agriculture.

## References

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**Table 1. Geographical Structure of the MIRAGE Model for the Growth Simulations**

Regions	Model designation	Description
United States	usam	
European Union	euro	EU-25 (as of May 2004) except Poland
Australia/New Zealand	aunz	
Rest of OECD	oecd	Hong Kong, Japan, Korea, Canada, Mexico, Switzerland, rest of EFTA
Latin America	amla	Bolivia, Colombia, Ecuador, Peru, Venezuela, Argentina, Brazil, Chile, Uruguay, rest of South America, <sup>1</sup> Central America, rest of Free Trade Area of the Americas, rest of the Caribbean
Middle income countries-Asia	mics	China, Taiwan, rest of East Asia, Indonesia, Malaysia, Philippines, Singapore, Thailand, Viet Nam, India, Pakistan, Sri Lanka, rest of South Asia
Low income countries-Asia	ldcs	Bangladesh, rest of South-East Asia
Middle income countries-Africa	micf	Morocco, Tunisia, rest of North Africa, Botswana, South Africa, Mauritius, Zimbabwe, Tanzania, rest of Southern Africa Development Community, Nigeria
Low income countries-Africa	ldcf	Rest of South African Custom Union, Malawi, Mozambique, Zambia, Madagascar, Uganda, rest of Sub-Saharan Africa.
Rest of the World	rotw	Albania, Bulgaria, Croatia, Poland, Romania, Russian Federation, rest of Former Soviet Union, Turkey, Iran, rest of Europe, rest of the Middle East, rest of Oceania, rest of North America

<sup>1</sup> "Rest of..." refers to countries in the specified region not listed separately in any of the country groupings.

**Table 2. Sectoral Structure of the MIRAGE Model for the Growth Simulations**

Group Sectors	Commodity sectors	Description
<i>Agro-food</i>	Rice	Paddy rice and processed rice
	Wheat	Wheat
	Other cereals	Cereal grains nec <sup>1</sup>
	Fruits and vegetables	Vegetables, fruits, nuts
	Oilseeds	Oilseeds
	Sugar	Sugar cane, sugar beets, sugar
	Plant based fibers	Plant based fibers
	Other agricultural products	Crops nec, wool, silk-worm cocoons
	Meat and meat products	Cattle, sheep, goats, horses, animal products nec, meat (cattle, sheep, goats, horses), meat products nec, vegetable oils and fats
	Milk	Raw milk, dairy products
Food products	Food products nec, beverage and tobacco products	
<i>Industry</i>	Forestry	Forestry
	Fish	Fish
	Other primary	Coal, oil, gas, mineral nec
	Textile and apparel	Textiles, wearing apparel, leather products
	Other manufactures	Wood products, paper products, publishing, electronic equipment, machinery and equipment nec, manufactures nec, electricity, gas manufacture, distribution
	Petroleum chemicals	Petroleum, coal products, chemicals, rubber, plastic products, mineral products nec, ferrous metals, metals nec, metal products
	Motor vehicles and equipment	Motor vehicles and parts, transport equipment nec
<i>Services</i>	Other services	Water, construction, communication, financial services nec
	Transport and trade	Trade, transport nec, sea transport, air transport

<sup>1</sup> "nec" indicates not elsewhere classified.

**Table 3. Effects on U.S. Agricultural Production and Trade from Higher Growth Rates among Selected Regions (percent change from baseline)**

	Production	Export	Import
	(in percent)		
Agriculture	0.32	2.88	1.74
Rice	1.92	7.12	5.29
Wheat	3.06	4.59	2.29
Other cereals	2.43	8.05	0.80
Fruits and vegetables	0.30	1.35	1.10
Oilseeds	0.38	0.51	2.47
Sugar	-0.05	-1.47	3.99
Plant based fibers	-0.46	-0.14	8.30
Other agriculture	-0.13	1.54	4.00
Meat and meat products	0.30	2.51	1.47
Milk	0.13	-0.26	0.55
Food products	0.27	3.45	1.43

Source: MIRAGE simulation results.

**Table 4. Effects on U.S. Agricultural Export Volume to Selected Regions with Higher Growth Rates**  
(percent change from baseline and percentage of total U.S. exports)

	Low income Africa (ldcf)	Middle income Africa (micf)	Importers Low income Asia (ldcs)	Rest of the World (rotw)	World
(in percent) <sup>1</sup>					
U.S. agriculture exports					
Rice	26.43	35.43	3.17	27.76	
	<i>7.94</i>	<i>2.55</i>	<i>0.75</i>	<i>16.95</i>	<i>100</i>
Wheat	32.08	17.73	15.73	25.96	
	<i>2.19</i>	<i>18.04</i>	<i>0.70</i>	<i>10.10</i>	<i>100</i>
Other cereals	31.27	40.70	24.00	46.61	
	<i>0.45</i>	<i>11.86</i>	<i>0.09</i>	<i>6.74</i>	<i>100</i>
Fruits and vegetables	25.65	33.45	19.27	38.60	
	<i>0.33</i>	<i>0.61</i>	<i>0.08</i>	<i>3.57</i>	<i>100</i>
Oilseeds	20.92	33.62	22.43	38.34	
	<i>0.05</i>	<i>1.14</i>	<i>0.00</i>	<i>4.03</i>	<i>100</i>
Sugar	14.01	23.94	13.74	26.74	
	<i>0.34</i>	<i>0.76</i>	<i>0.02</i>	<i>2.15</i>	<i>100</i>
Plant based fibers	20.72	21.02	12.18	28.18	
	<i>0.00</i>	<i>0.13</i>	<i>3.44</i>	<i>9.32</i>	<i>100</i>
Other agriculture	5.62	20.86	16.41	32.57	
	<i>0.55</i>	<i>1.14</i>	<i>0.17</i>	<i>7.10</i>	<i>100</i>
Meat and meat products	9.67	19.34	7.69	25.43	
	<i>0.53</i>	<i>1.34</i>	<i>0.09</i>	<i>11.37</i>	<i>100</i>
Milk	24.61	24.28	9.68	21.22	
	<i>0.42</i>	<i>1.30</i>	<i>0.15</i>	<i>5.94</i>	<i>100</i>
Food products	22.65	31.21	13.89	35.24	
	<i>0.69</i>	<i>1.65</i>	<i>0.10</i>	<i>8.82</i>	<i>100</i>

<sup>1</sup> For each commodity top line is increase in exports to the region; second line is region's share of total U.S. exports.  
Source: MIRAGE simulation results.

**Table 5. Effects on U.S. Agricultural Production and Trade from Alternative Scenarios (percent change from baseline)**

	Production	Export	Import
(in percent)			
Alternative scenarios			
A1: 4% minimum growth	0.00	0.00	0.08
A2: 5% minimum growth	0.12	1.03	0.66
A3: The main simulation with TFP growth for agriculture equal to non-agriculture	0.19	1.75	2.17
A4: 7% growth in amla and four initial regions	-0.29	-0.10	8.93
A5: Reduced growth rate for mics to 3%	-0.29	-4.12	-2.01

Source: MIRAGE simulations.

## Brief description of the MIRAGE model

MIRAGE is a multi-region, multi-sector CGE model that incorporates a sequential dynamic set-up. There is full employment of labor and other resources within each country/region and these factor endowments can not be moved internationally. Either perfect or imperfect competition can be assumed for industrial sectors. Goods produced by different countries/regions are imperfect substitutes. As in other CGE models, a set of assumed “trade elasticities” influence the extent to which consumer choices among domestic and foreign goods are affected by changes in their relative prices. In MIRAGE, substitutability between intermediate goods used in the production process is also modeled, and again depends on relative prices. The only factor of production for which supply is constant, is natural resources. Labor grows with projected population growth, the capital stock can increase with investment, and land can be brought into or removed from production in response to higher or lower returns. Skilled labor is the only factor perfectly mobile within each country/region. Capital is sector-specific and unskilled labor has somewhat limited mobility between agriculture and non-agriculture.

The macroeconomic closure assumes that the current account is constant and equal to its initial value leaving the real exchange rate to adjust to balance the current-account equation.

