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Economic Growth,
Technological Change,
and Patterns of Food
and Agricultural Trade in Asia

Thomas W. Hertel, Carlos E. Ludena,
and Alla Golub

November 2006

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ECONOMIC GROWTH, TECHNOLOGICAL CHANGE, AND PATTERNS OF FOOD AND AGRICULTURAL TRADE IN ASIA

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NOVEMBER 2006

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FOREWORD

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ABSTRACT

This paper projects global food supply and demand to the year 2025, with a particular emphasis on Asia. Technological change is found to be the critical factor in determining whether or not food prices will preserve their long-run, downward trend, as well as the likely patterns of trade and structural change. Historical and projected rates of total factor productivity (TFP) growth are decomposed into outward movement in the frontier and “catching up” to the world frontier. Overall, the baseline scenario reduces the poverty headcount ratio in People’s Republic of China (PRC) by more than 80 percent. In the Association of Southeast Asian Nations (ASEAN) it falls by about 40%. However, in South Asia, the falling headcount ratio (17%) is insufficient to lower aggregate poverty, due to the relatively strong rise in the region’s population. In the baseline projections, crop productivity in the ASEAN region declines by 0.4%/year. This reflects decades of neglect in research expenditures. In an alternative scenario, future ASEAN crop TFP is raised to the Asia-wide rate of 0.95%/year. This alternative scenario boosts production in nearly all sectors of the economy, and lowers the poverty headcount ratio by an additional 14%. This could be expected to lift more than 30 million additional people out of poverty in the ASEAN region.

I. MOTIVATION AND OVERVIEW

As growth in Asia continues to outpace growth in the rest of the world, attention has once again focused on primary commodity markets. Rapidly growing demands, coupled with relatively inelastic supply, have been boosting prices for agricultural, energy, and mineral products. This paper projects potential outcomes in this footrace between supply and demand for the year 2025, with a particular emphasis on food markets. The paper begins with an in-depth analysis of the fundamental drivers of change, including per capita consumer demand, population growth, accumulation of capital and labor, endowments of land by agro-ecological zone, as well as technological change. Technological change is found to be the critical factor in determining whether food prices will reverse their long-run, downward trend, as well as the likely patterns of trade and structural change. Yet this aspect of economic growth is still not well understood.

The paper focuses considerable attention on the measurement of worldwide technological progress in agriculture over the past 40 years. Emphasis is placed on total factor productivity (TFP) growth, which is shown to behave very differently from the widely used partial factor productivity measures of output per hectare and output per head of livestock. Historical rates of TFP growth are shown to vary widely across countries and also across subsectors within agriculture (e.g., crops vs. livestock). TFP growth is decomposed into that component owing to “catching up” to the current technology frontier, and that due to an outward movement in the frontier. In projecting future TFP growth, these components are separately modeled, which makes a big difference for Asia, where much of the past TFP growth has been fueled by catching up. This will not continue indefinitely, and it accounts for the eventual slowing down of TFP growth in agriculture particularly in the People’s Republic of China (PRC).

The relative rates of TFP growth between agriculture, manufacturing, and services also play an important role in projections of structural change. Here, the paper draws heavily on the work of the Kets and Lejour (2003) who examine sector growth rates in the Organisation for Economic Co-operation and Development (OECD) over the past two decades. They find that TFP has grown fastest in agriculture, followed by manufactures, and then services. However, they also find a great deal of variation within the services sector, with transportation and communications growing exceptionally fast, while TFP in nontraded services grows much more slowly. These relative rates of TFP growth across sectors are taken into account in the paper’s projections to 2025. Building on aggregate growth projections from the World Bank, regions of the world are divided into five overall TFP growth rates, giving rise to a set of real gross domestic product (GDP) forecasts that are broadly in line with World Bank projections, but which differ in particular cases due to the fact that the international movement of capital is explicitly modeled.

Discussion of the baseline results focuses on structural change in the global economy, with a particular focus on developing Asia. Patterns of consumption and production as well as changes in net trade positions are examined. The paper also focuses on factor markets, including the likely sources of sector employment for factors of production, as well as factor returns, and ultimately

prices. Together with information on the pattern on income and spending at the poverty line, this permits general conclusions about the likely changes in poverty over the baseline period to be drawn.

II. DRIVERS OF CHANGE: INCOME AND POPULATION

There is a long tradition of forecasting demand for commodities based on per capita income and population. At constant per capita income and unchanging prices, uniform population growth worldwide simply translates into uniform growth in the demand for all goods and services. However, population growth tends to be higher in countries with lower per capita income, and, since poorer households tend to spend a higher portion of their income on food, population growth tends to boost the relative importance of food consumption worldwide. On the other hand, growth in per capita income has the opposite effect: as households become richer, their expenditure share on food tends to fall. Also the composition of food expenditures shifts from staple products, aimed at fulfilling caloric requirements, to animal protein, edible oils, fruits, and vegetables as consumer incomes rise above the poverty line.

These points are illustrated in Figure 1, which shows the predicted expenditure shares on an exhaustive grouping of commodities and services for the ASEAN region as a whole in 1997. The horizontal axis shows per capita incomes in US dollars. (These need to be multiplied by about a factor a four to get to purchasing power parity [PPP] international dollars.) The first vertical line in this figure shows the \$2/day (PPP basis) poverty line. At this per capita income level, the largest expenditure item is staple grains, followed by processed food, beverages and tobacco, and housing. Expenditure on meat, dairy, and fish is much lower. The total food expenditure share at this level of income is estimated to be about 45%. Clearly population growth in this income class translates into a strong increase in food demand, relative to other goods and services.

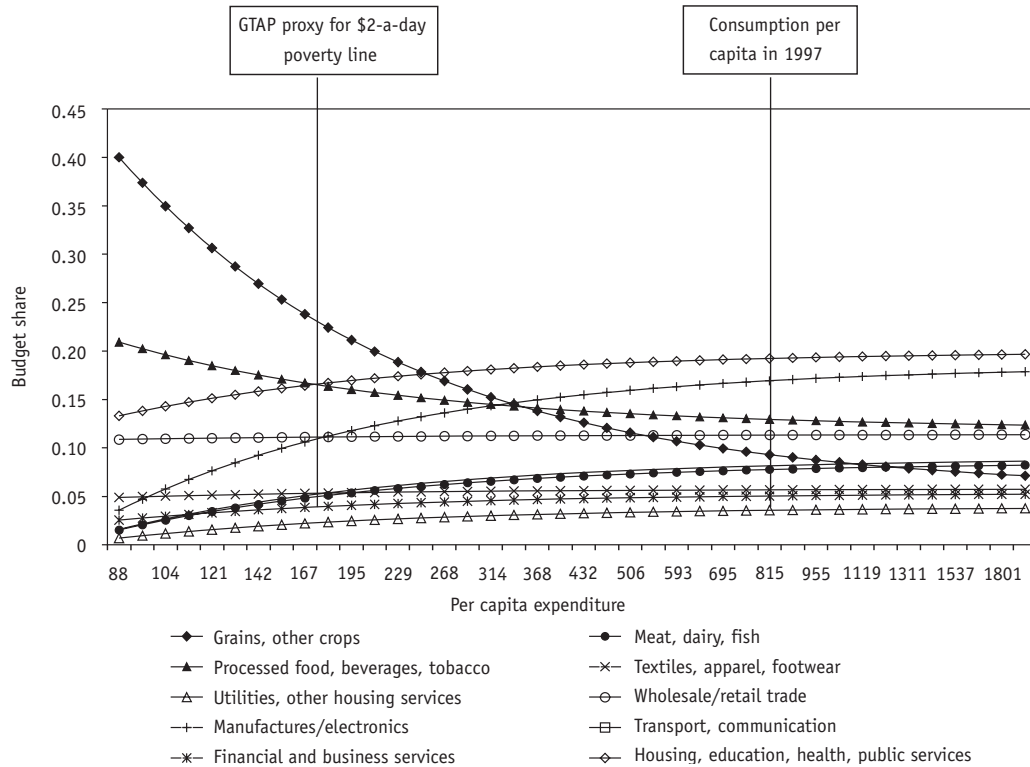
The second vertical line in the figure shows the expenditure shares for individuals at the 1997 average income level in the ASEAN region. At this point, staple grains expenditures have fallen below many other items in the budget, and the total expenditure share on food is now well under one third of the total household budget, and is continuing to fall at the margin. At this point, housing, health and education services, and manufactured items dominate the budget. Thus, overall income growth in ASEAN (i.e., rising per capita income) fuels a *relative* decline in the demand for food.

The predicted budget shares in Figure 1 are based on an econometrically estimated *demand system*. The system approach is much preferable to the estimation of individual demand equations, particularly in an economywide projections approach such as that used in this paper. In the single equation approach, there is no guarantee that households will remain within their budget constraints—expenditures for all goods could increase without a corresponding rise in income. This is not possible in the systemwide approach. In addition, the system approach also takes account of the full range of substitution possibilities among goods and services. The estimates used in this paper are based on the work of Hertel and Reimer (2004). Those authors estimate the demand system using the GTAP version 5.4 global data base.¹ This has the great advantage of making the estimates directly usable in the projections model used in this paper. Those authors also show that the behavior of demand in their estimated model follows closely that in a model estimated

¹ Before incorporation in the current model, the estimates must be calibrated to eliminate the error term for each country. The calibration procedure is described in Golub (2006).

based on the widely used International Comparisons Project database. However, mapping the latter to the GTAP database is highly problematic. So they prefer to use the estimates obtained directly from the GTAP database.

FIGURE 1
SPENDING PATTERNS ACROSS THE INCOME SPECTRUM IN ASEAN

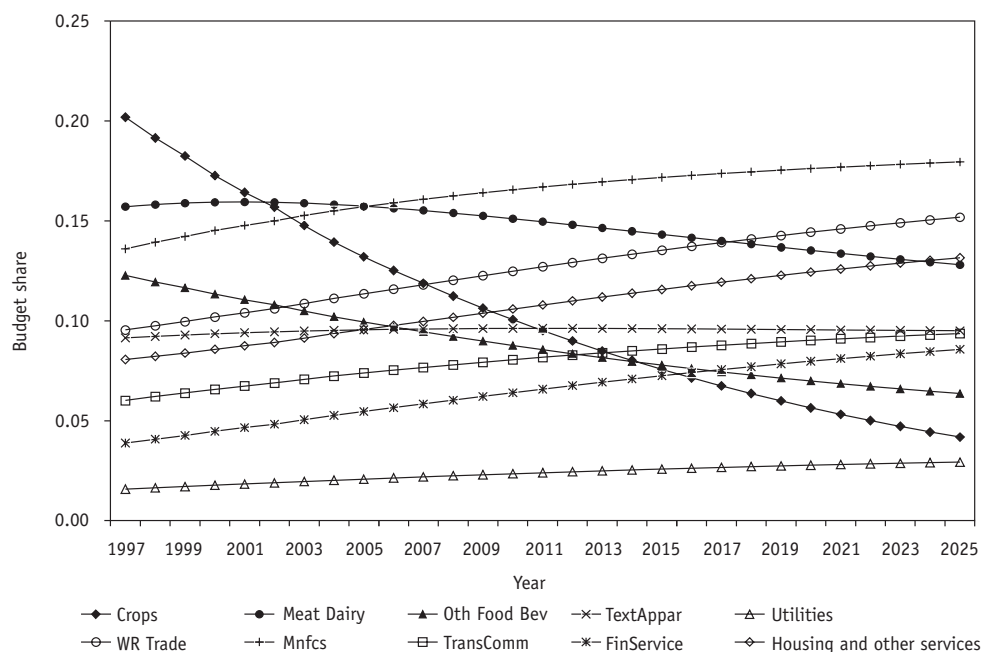


With a complete demand system in hand, the pattern of national consumer demand in 2025 could be projected. The impact of income growth on the pattern of consumer expenditure can be illustrated by shocking income per capita by the cumulative growth in this variable over the 1997–2025 period assuming constant prices for all goods and services. Figure 2 shows the results for the PRC, the economy with the highest per capita income growth rate over this period. In the initial year (1997), total spending on food, beverages, and tobacco is about 48% of the per capita household’s expenditures. This falls over the projection period, most sharply for staple grains; followed by processed food; and finally also by meat, dairy, and fish (from about 2005 onward). By the end of the projection period, the per capita expenditure share on food in the PRC is under one-quarter. Of course this does not mean that total spending on food products falls, since income and population are growing strongly over this period. However, it does mean that this growth is much more modest than for products with a high income elasticity of demand (e.g., housing services).

The rate of demand growth in the model regions over the projections period (at constant prices) is reported in the first two sets of rows in Table 1 (Demand only).² This demand-side growth has

² Specifically, we have provided the regions with perfectly elastic factor supplies at constant prices to accommodate the growth in demand.

FIGURE 2
 PROJECTED AVERAGE BUDGET SHARES IN THE PRC



Note: Projections are obtained using GAMS and based on projected income per capita growth calculated using GTAP baseline (Walmsley et al. 2000) and assuming constant prices, i.e., in partial equilibrium framework. The initial AIDADS estimates reported in Reimer and Hertel (2004) are calibrated to fit the initial structure of consumption in the PRC.

been decomposed into the contribution from population growth, at constant per capita income,³ and that stemming from both population growth and per capita income growth. When population grows but per capita income does not (income growth just keeps pace with population), per capita demand for each product category is unchanged, and aggregate demand grows at the rate of population growth in each region. This growth is highest in Sub-Saharan Africa (SSA) and Middle East and North Africa (MENA) regions; and lowest in Economies in Transition (EIT) and Western European Union (WEU).

When per capita income is also permitted to grow, the cumulative growth in demand by sector is much larger for all of the aggregate consumption categories, but particularly so for those with higher income elasticities of demand. Meat/dairy/fish products, manufactured goods, and most of the services categories all show very strong growth under this demand-side scenario. On the other hand, staple grains/crops category shows the lowest cumulative growth rates over this 28-year period.

The final row (boldface) in Table 1 shows the cumulative growth in consumption, by demand category, when supply-side constraints are brought to bear. In this case, prices adjust to clear the factor and commodity markets, and this tends to reduce demand growth in many cases. This is most striking in the case of the PRC, where supply-side constraints result in significantly lower demand growth than would be predicted from the demand side alone. More discussion of this case will be provided below, once we have discussed the supply side of the projection scenario.

³ Technically, per capita utility is fixed for the representative regional household over the projection period.

TABLE 1
IMPACT OF POPULATION AND INCOME GROWTH ON CONSUMER DEMAND: CUMULATIVE GROWTH 1997–2025 (PERCENT)

SECTOR	ANZ	PRC	HVAsia	ASEAN	SAsia	NAm	LAm	WEU	EIT	MENA	SSA
Crops											
Dmd only	23	20	3	40	46	23	41	-1	-3	59	79
pop&inc	88	515	19	117	278	74	161	52	128	157	154
DmdSupply	21	192	25	68	122	17	58	31	93	138	106
Meat/ Dairy/ Fish											
Dmd only	23	20	3	40	46	23	41	-1	-3	59	79
pop&inc	130	3165	97	241	514	151	198	89	247	168	256
DmdSupply	1	404	0	2	111	87	39	9	142	88	22
Other Food/ Beverage and Tobacco											
Dmd only	23	20	3	40	46	23	41	-1	-3	59	79
pop&inc	115	883	84	172	124	99	143	73	170	164	192
DmdSupply	64	434	62	103	96	74	67	59	142	185	138
Textiles/ Apparel											
Dmd only	23	20	3	40	46	23	41	-1	-3	59	79
pop&inc	250	2040	198	307	464	223	221	175	256	274	318
DmdSupply	135	1263	159	223	473	125	120	110	242	229	225
Utilities/ Household Services											
Dmd only	23	20	3	40	46	23	41	-1	-3	59	79
pop&inc	103	1611	67	159	323	89	139	79	149	150	170
DmdSupply	126	855	103	202	538	93	103	88	126	152	204
Wholesale/Retail Trade											
Dmd only	23	20	3	40	46	23	41	-1	-3	59	79
pop&inc	128	1633	81	157	272	97	150	86	175	154	159
DmdSupply	126	778	110	296	495	90	152	91	150	215	216
Manufactures											
Dmd only	23	20	3	40	46	23	41	-1	-3	59	79
pop&inc	191	2226	133	275	481	169	189	138	205	230	270
DmdSupply	126	1329	134	216	401	104	110	93	200	203	206

continued.

Table 1. continued.

SECTOR	ANZ	PRC	HYAsia	ASEAN	SAsia	NAM	LAM	WEU	EIT	MENA	SSA
Transport/ Commun	23	20	3	40	46	23	41	-1	-3	59	79
pop&inc	162	2055	118	221	475	149	176	115	243	199	235
DmdSupply	53	816	104	112	274	56	48	20	158	117	127
Financial											
Services	23	20	3	40	46	23	41	-1	-3	59	79
pop&inc	131	2756	82	208	343	95	171	87	215	181	173
DmdSupply	146	1380	122	311	619	113	196	111	224	263	254
Housing/ Education/ Health	23	20	3	40	46	23	41	-1	-3	59	79
pop&inc	132	1974	77	200	266	97	175	90	215	188	162
DmdSupply	133	894	115	277	598	98	152	96	168	256	208

ANZ means Australia and New Zealand.
 ASEAN means Association of Southeast Asian Nations.
 EIT means Economies in Transition.
 HYAsia means High-Income Asia.
 LAM means Latin America.
 MENA means Middle East and North Africa.
 NAM means North America.
 PRC means People's Republic of China.
 ROW means Rest of the World.
 SAsia means South Asia.
 SSA means Sub-Saharan Africa.
 WEU means Western European Union except Turkey.

Note: "Pop" (population only) involves fixing per capita income as well.
 In the "Dmd only" (demand only) scenarios, prices are fixed exogenously and endowments are in perfect supply.
 Source: Ludena et al. (2006.)

III. DRIVERS OF CHANGE: ENDOWMENTS

Of course it is unrealistic to assume that prices will not change, and changing prices will also affect the pattern of demand (as noted in Table 1), as well as patterns of trade and production. So we must bring in the supply side of the picture to allow endogenous determination of these important variables. This involves projecting changes in labor supply (both skilled and unskilled). However, investment and hence capital stock are determined endogenously in the model, as will be discussed below. The cumulative growth rates in skilled and unskilled labor supplies have been obtained from the GTAP v.5 baseline (Walmsley, Dimaranan, and McDougall 2000) and are reported in the first two columns of Table 2. Note that there is substantial variation within regions, as well as internationally. Cumulative growth in the unskilled workforce over this period ranges from -2% in the economies of Eastern and Central Europe and the former Soviet Union, to nearly 100% in Sub-Saharan Africa. Projected growth in the skilled labor force is particularly strong in developing Asia, as well as Latin America.

TABLE 2
CUMULATIVE GROWTH RATES IN ENDOWMENTS AND GDP, BY REGION (PERCENT)

REGION	UNSKILLED LABOR	SKILLED LABOR	PRODUCTIVITY (GROWTH RATE PER YEAR)	ENDOGENOUS VARIABLES		WB CAPITAL	WB GDP
				CAPITAL	GDP		
1	2	3	4	5	6	7	8
ANZ	55	26	1	250	148	213	145
PRC	26	173	5	553	607	958	629
HYAsia	16	26	1.5	51	64	130	103
ASEAN	68	260	2	534	275	263	215
SAsia	66	222	3.5	731	413	368	326
NAM	49	28	1	239	132	117	163
LAM	43	206	1	286	172	197	114
WEU	26	10	1	114	82	121	100
EIT	-2	13	3	96	152	151	151
MENA	69	178	1	126	143	141	148
SSA	96	146	1	376	225	202	176

ANZ means Australia and New Zealand.

ASEAN means Association of Southeast Asian Nations.

EIT means Economies in Transition.

HYAsia means High-Income Asia.

LAM means Latin America.

MENA means Middle East and North Africa.

NAM means North America.

PRC means People's Republic of China.

ROW means Rest of the World.

SAsia means South Asia.

SSA means Sub-Saharan Africa.

WEU means Western European Union except Turkey.

WB means based on World Bank projections.

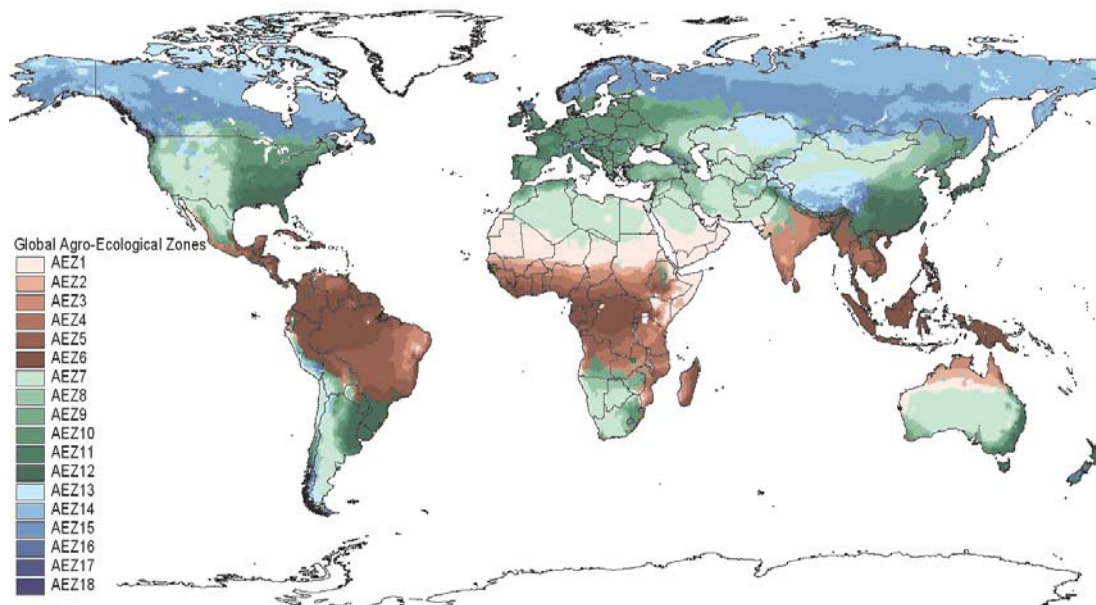
GDP means gross domestic product.

Note: Source for skilled and unskilled labor growth is Walmsley et al. (2000); productivity projections are discussed in the text. Capital stocks and GDP are endogenously determined.

In addition to the labor force, it is important to think about land and natural resource endowments as well. We assume that these factors are in fixed aggregate supply. For example, barring a substantial rise in sea level in the next two decades, it seems reasonable to assume that the total stock of land is in fixed supply. However, the quality of land varies widely across countries as well as within countries, constraining the kinds of activities that can be undertaken on the land. For this reason, the recently developed GTAP land use database is incorporated into the analysis (Lee et al. 2005). This database builds on the pioneering work of the Food and Agriculture Organisation (FAO) and International Institute for Applied Systems Analysis, in which they create the concept of agroecological zones (AEZs). These are homogeneous units of land that exhibit similar growing conditions as determined by temperature, precipitation, soil, and topography. When combined with a model of crop growing requirements, the length of growing period for each parcel of land can be predicted. The AEZs are grouped according to 6- and 60-day intervals.

Once a climate map is created, distinguishing boreal, temperate, and tropical climates, a total of 18 AEZs is obtained. The world map of GTAP-AEZs is shown in Figure 3. Note that most of Southeast Asia falls in the tropical, long-growing period AEZs. However, South Asia is more varied in its agroecological zone endowments, while the PRC contains a great range of AEZs particularly in the tropical and boreal categories.

FIGURE 3
GLOBAL DISTRIBUTION OF AGROECOLOGICAL ZONES



A critical part of using these AEZs for projections purposes hinges on knowing what activities can be undertaken on each AEZ, and the relative productivity of the different land types in each crop, livestock, or forestry enterprise. This is where most of the work has been required in building the GTAP-AEZ database. The model to be used for projections replaces the single set of market clearing conditions for land (standard GTAP model). Six different sets of market clearing conditions are assigned, one for each AEZ/growing period (the model abstracts from climatic differences here). The participation of each activity in these different land markets is dictated by the GTAP-AEZ database. This information will also shape the ability of agriculture and forestry to respond to the changing composition of demand as the global economy grows to 2025. For longer-run simulations, it is possible to use climate change forecasts to revise the global distribution of AEZs. Thus, for example, with global warming, the temperate zone would move northward in America, Asia, and Europe, and longer-growing periods would also move northward. In this way changes in the natural endowments of an economy over time can be reflected in the projections.

IV. DRIVERS OF CHANGE: TECHNOLOGICAL PROGRESS

As will be seen below, the most important piece of the projections relates to the rate of technological progress by sector, by region, and globally. Unlike the labor force and land endowments, technological progress is not directly observable. So understanding how technological progress has evolved in the past—a key requisite for making projections into the future—is itself a challenging task. Furthermore, there are many competing definitions of technological progress, and each of these has quite different implications for projections. In an effort to address some of these limitations, we have made technological progress a centerpiece of this paper. In keeping with the emphasis on structural change in food, most of the attention will be devoted to agriculture. However, competition for finite endowments between agriculture and nonagriculture will be driven in part by relative rates of TFP growth. In addition, overall TFP growth will drive economic growth, capital accumulation, and national income, thereby stimulating demand. TFP growth in manufacturing and services sectors will also be discussed in the projections.

A. Historical Analysis of Agricultural Productivity Growth

Productivity measurement in agriculture has captured the interest of economists for a long time. Coelli and Rao (2005) present a review of multicountry agriculture productivity studies, reporting a total of 17 studies in the decade between 1993 and 2003. Most of the studies on productivity growth in agriculture have focused on sectorwide productivity measurement, with less attention to the estimation of subsector productivity. This omission is not because of a lack of interest, but rather for reasons of data availability on input allocation to individual activities. Because of this lack of information, subsector productivity has usually been assessed using partial factor productivity (PFP) measures such as “output per head of livestock” and “output per hectare of land.” However, PFP is an imperfect measure of productivity. For example, if increased output per head of livestock is obtained by more intensive feeding of animals, then TFP growth may be unchanged, despite the apparent rise in PFP of land. In general, the issue of factor substitution can lead PFP measures to provide a misleading picture of performance (Capalbo and Antle 1988).

A more accurate measure of productivity growth must account for all relevant inputs, hence the name *total* factor productivity. However, TFP measurement requires a complete allocation of inputs to specific agricultural subsectors. For example, how much labor time was allocated to crop production

and how much to livestock production on any given farm, or in a given country? Given the importance of this problem, the literature is extensive on this topic. The most important contribution, from the standpoint of this paper, is that of Nin et al. (2003) who propose a directional Malmquist index that finesses unobserved input allocations across agricultural sectors. They use this methodology to generate multifactor productivity measure for crops and livestock sectors. This technique forms the basis for the analysis presented here (see Ludena et al. 2006 for more details).

A key part of this historical analysis is the decomposition of productivity growth into two components: technical change, or movement in the technology frontier for a given subsector, and “catching up”, which represents improvements in productivity that serve to bring the country in question closer to the existing, global frontier (Färe et al. 1994). Forecasts of future productivity growth must distinguish between these two elements of technical progress, and this is reflected in the model’s approach to forecasting future technology.

Data for inputs and outputs were collected principally from FAOSTAT 2004 and covered a period of 40 years from 1961 to 2001. The data included 116 countries considering three outputs (crops, ruminants, nonruminants); and nine inputs (feed, animal stock, pasture, land under crops, fertilizer, tractors, milking machines, harvesters and threshers, labor). To estimate the disaggregate TFP measures for crops, ruminants, and nonruminants, five allocable inputs are assumed: land under crops is allocated to crops, ruminant stock and milking machines to ruminants, and nonruminant stock to nonruminants. In addition, feed is allocated to livestock but cannot be allocated between ruminants and nonruminants. All other inputs remain unallocable to outputs and factor only into the determination of the overall frontier for agriculture.

The results of the historical TFP analysis are summarized in Table 3, along with projections from 1997–2025, which will be used in subsequent simulations. Historical productivity measurement and forecasts for eight broad regions of the world are shown by country in Appendix Table A2.1. The three agricultural subsectors with reported directional TFP measures are crops, ruminants, and nonruminants. For each agricultural subsector, Table 3 reports the average change in TFP, as well as the change in efficiency (EFF = catching up) and technical change (TCH = outward movement in the technology frontier) derived from the directional Malmquist index, both for the historical period and for the 28-year projection period 1997–2025.

The global agricultural productivity estimates are shown in Table 3, as well as those for aggregate agriculture, created as an adjusted, share-weighted sum of the individual regions’ crops, ruminants, and nonruminant productivity measures.⁴ The shares used in this process are based on the value of production in 2001, as reported by FAO (see Ludena et al. 2006), Appendix Table A3. These directional measures are adjusted by a region-specific adjustment factor so that they are consistent with the aggregate agriculture productivity estimate calculated from the traditional Malmquist index (Ludena et al. 2006). Not only does this ensure comparability with other studies of agricultural TFP, it also renders these estimates usable in projection frameworks that do not embody the directional productivity concept.

⁴ An alternative would be to estimate TFP for aggregate agriculture directly using the same distance function approach, this time nondirectional (since there is only one output involved). This is the approach of Nin et al. (2004), for example. While this would offer a preferred estimate of aggregate agriculture productivity, it has a significant drawback for present purposes, namely it is inconsistent with the subsector measures. Therefore, aggregate agricultural productivity is reported using the weighted subsector measures in order to offer a more consistent analysis of TFP growth worldwide, building up from the subsector level.

TABLE 3
HISTORICAL AND PROJECTED AVERAGE TOTAL FACTOR PRODUCTIVITY GROWTH RATES BY REGION AND SECTOR (PERCENT GROWTH)

REGIONS/SECTORS	PERIOD	CROPS			RUMINANTS			NONRUMINANTS			WEIGHTED AVERAGE		
		TFP	EFF	TCH	TFP	EFF	TCH	TFP	EFF	TCH	TFP	EFF	TCH
World	1961-00	0.72	-0.03	0.75	0.62	-0.03	0.65	2.10	-1.08	3.23	0.94	-0.22	1.17
	1997-25	1.02	0.33	0.69	1.22	0.58	0.64	3.14	0.89	2.21	1.43	0.47	0.96
	1961-70	2.22	-0.25	2.48	0.27	-2.59	2.93	4.32	0.46	3.84	2.71	-0.20	2.92
	1971-80	-2.24	-2.81	0.59	-2.01	-2.75	0.76	-0.50	-3.64	3.27	-1.70	-3.06	1.41
PRC	1981-90	0.93	0.84	0.09	7.12	6.99	0.12	5.36	-5.09	11.01	2.71	-0.51	3.39
	1991-00	2.11	2.06	0.05	6.22	6.19	0.03	4.26	0.91	3.33	3.05	2.01	1.04
	1961-00	0.74	-0.06	0.80	2.82	1.85	0.95	3.33	-1.88	5.31	1.67	-0.47	2.17
	1997-25	1.41	0.71	0.70	3.42	2.58	0.82	6.47	2.75	3.62	3.07	1.46	1.59
East and South East Asia	1961-70	0.27	-0.56	0.84	-0.15	-1.58	1.46	1.96	0.10	1.86	0.48	-0.52	1.01
	1971-80	0.99	0.40	0.59	1.16	0.63	0.52	1.52	0.00	1.52	1.07	0.36	0.71
	1981-90	-0.67	-0.85	0.18	-1.91	-2.20	0.30	1.02	-4.22	5.54	-0.49	-1.38	0.93
	1991-00	-0.48	-0.50	0.02	0.05	-0.41	0.46	0.53	-1.84	2.42	-0.32	-0.68	0.37
South Asia	1961-00	0.02	-0.38	0.40	-0.22	-0.90	0.69	1.25	-1.51	2.82	0.18	-0.56	0.75
	1997-25	-0.39	-0.74	0.35	-0.90	-1.50	0.62	3.23	0.75	2.45	0.09	-0.56	0.66
	1961-70	-0.13	-1.08	0.97	-0.97	-1.73	0.78	2.23	0.70	1.51	-0.24	-1.17	0.95
	1971-80	-0.62	-0.96	0.34	-0.40	-0.73	0.34	0.02	-1.74	1.81	-0.55	-0.93	0.39
Economies in Transition	1981-90	0.38	0.23	0.15	1.36	1.34	0.02	3.01	-2.06	5.23	0.69	0.41	0.29
	1991-00	1.07	0.96	0.10	1.43	0.68	0.74	2.32	0.05	2.27	1.19	0.87	0.32
	1961-00	0.17	-0.22	0.39	0.35	-0.12	0.47	1.89	-0.77	2.69	0.27	-0.21	0.48
	1997-25	0.95	0.58	0.37	1.40	0.95	0.44	3.13	0.89	2.21	1.12	0.67	0.44
Middle East and North Africa	1961-00	1.13	-0.24	1.38	0.28	-0.19	0.47	1.20	-0.68	1.91	0.89	-0.29	1.19
	1997-25	1.75	0.65	1.08	0.51	-0.05	0.56	2.41	0.75	1.62	1.48	0.46	1.01
	1961-00	-0.03	-0.24	0.21	-0.02	-0.54	0.52	0.64	-0.22	0.87	0.03	-0.30	0.34
	1997-25	0.38	0.18	0.20	-0.29	-0.78	0.50	-0.22	-1.08	0.89	0.19	-0.14	0.33
Latin America and Caribbean	1961-00	0.15	-0.08	0.22	0.36	-0.03	0.40	0.50	-0.25	0.76	0.21	-0.08	0.29
	1997-25	0.99	0.74	0.25	0.58	0.23	0.35	0.03	-0.62	0.66	0.85	0.56	0.29
	1961-00	0.76	-0.33	1.10	0.08	-0.78	0.87	2.01	-0.87	2.91	0.77	-0.53	1.30
	1997-25	0.83	-0.28	1.12	1.35	0.58	0.76	4.66	2.08	2.51	1.52	0.28	1.23
Industrialized Countries	1961-00	1.47	0.53	0.93	0.71	0.05	0.66	1.23	-0.36	1.61	1.19	0.20	0.99
	1997-25	1.21	0.31	0.89	0.39	-0.28	0.67	0.75	-0.69	1.46	0.87	-0.07	0.94

TFP means total factor productivity.
EFF means efficiency change.
TCH means technical change.
Note: Productivity growth rates for Agriculture are estimated weighted shares of each subsector in agriculture for each period.

The top right hand corner in Table 3 suggests that global agricultural TFP grew over the 1961–2000 period at an annual rate of 0.94%. Total factor productivity growth may be decomposed into that portion due to an outward shift in the production possibilities frontier and that due to the average degree of “catching-up” of individual regions to this dynamic frontier. From the entries in the top right hand corner of Table 3, it is clear that, taking into account the production-weighted averages of different regions/subsectors, the frontier in agriculture advanced more rapidly (1.17%/yr) than individual regions’ TFP, thereby leading to negative technical efficiency growth (–0.22%/yr). World average TFP growth has been increasing over the past three decades, rising from 0.11%/year in the 1970s to 1.52%/year in the 1990s, due to accelerating productivity growth in those developing regions where substantial economic reforms have taken place since 1980 (PRC, Eastern Europe and the former Soviet Union, Latin America, and Sub-Saharan Africa).

Breaking up aggregate agricultural TFP growth into subsectors, for the world as a whole, nonruminant productivity growth (2.1%/year) far outstripped that in the other subsectors. This high rate of TFP growth has been fueled by a rapidly advancing frontier, with technological change estimated to be more than 3.2%/year over this 40-year period. As a consequence, virtually all regions have fallen further away from the frontier (negative technical efficiency growth rates averaging –1.08%/year) over this period.

In the case of ruminants, the same general pattern as with nonruminant livestock productivity growth exists, although growth in the frontier has been much slower, and the industrialized countries have, as a group, been marginally increasing their technical efficiency, although all other regions have been falling back from the frontier. Overall TFP growth in ruminants has been about 0.62% per year. For crops, TFP growth has been about 0.72% per year, with a somewhat more rapid growth in the frontier than for ruminants. Once again, all of the developing country regions have been falling away from the frontier, with the rate of catch-up in industrialized countries offsetting this, so that world average efficiency growth is almost zero.

The first region of the world displayed in Table 3 is the PRC. Productivity growth in the PRC has been notoriously hard to measure due to the tendency for output statistics to be artificially inflated in order to meet pre-established planning targets. However, there is little doubt that the TFP performance of agriculture in the PRC has been strengthening since the 1970s, when it declined at an average rate of nearly 2%/year. This improvement is particularly striking in the case of livestock production, where productivity growth in the 1980s and 1990s has been extraordinarily high. In the case of ruminant production, most of this TFP growth—between 6 and 7% per year over the past two decades—is attributed to “catching up” to the technological frontier. On the other hand, growth in nonruminant productivity appears to have been driven by outward movement in the technological possibilities facing this sector.

The PRC is followed in Table 3 by East and Southeast Asia. This regional grouping reflects FAO data on 14 countries, including much of ASEAN as well as both Republic of Korea and North Korea (see Appendix Table A2.1). As such, it is a rather heterogeneous grouping of economies for which crop production is dominant (82% of the value of output; see Table A3). A very modest weighted rate of TFP growth is estimated for this region of just 0.18%/year, with negligible growth in crop TFP over the 1961–2001 period. In fact, in contrast to other regions, crop TFP appears to have fallen since the 1970s. Nonruminant productivity growth is the only bright spot for East and Southeast Asia, with a 1.25% annual growth rate over the 40-year historical period.

The next region reported in Table 3 is South Asia. Due to the fact that the efficiency series for this region were 1 for all years in the sample, it was not possible to model these series using the logistic function, an essential step in constructing the forecasts. To solve this problem, a composite of all developing countries in Asia is used to estimate this block. So this block includes the preceding two regions (the PRC, East and Southeast Asia), as well as South Asia and several countries in the near East. This is clearly a limitation of the present study, but it does permit us to obtain an exhaustive set of estimates for the world as a whole, which is the ultimate goal. For this region, slow but positive productivity growth is observed in crops and ruminant livestock, with faster growth in nonruminants.

The next region in this table includes the Economies in Transition (Eastern Europe and former Soviet Union). As the name indicates, these comprise a group of economies that have undergone very substantial changes in the past decade and a half. Their TFP growth record reflects this. Indeed, the decade of the 1970s shows negative TFP growth in this region (Ludena et al. 2006). This is followed by some improvement in the 1980s and rapidly accelerating productivity growth in the 1990s, following the collapse of the Soviet Union and the opening up of the Eastern bloc. This acceleration is particularly striking in the case of crops and nonruminant livestock production.

The Middle East and North Africa is the next region covered by the estimates in Table 3. Much like South and Southeast Asia, the lack of growth in crop and ruminant TFP leads to negligible aggregate productivity growth, with nonruminants being the only subsector with a reasonably strong performance over the historical period. In contrast to the Middle East and North Africa, Sub-Saharan Africa shows modest TFP growth across all three subsectors, with a marked improvement in crop productivity since the structural adjustment reforms of the 1980s. In fact, the overall weighted average rate of productivity growth for this region over the 1990s is 0.79% per year (Table A4).

The Latin America and Caribbean region also shows accelerating growth in TFP particularly in the 1990s when Brazil in particular undertook major rural sector reforms. This jump in TFP growth is most noticeable in crops and nonruminants. The overall average rate of productivity growth across all subsectors is nearly 1.7%/year in this region over the 1991–2001 period (Table A4).

Finally, turning to the block of entries in Table 3 representing TFP growth rates in the industrialized countries, it is quite striking that where the share of consumer expenditure on food is relatively low, and only a small portion of the labor force is employed in agriculture, productivity growth rates are much higher; indeed, 40% above the world average (which includes these countries) for the historical period. This higher growth rate is fueled strongly by high TFP growth in the crop subsector (1.47%/year). Industrialized country TFP growth in the crop sector is followed in size by nonruminants (1.23%/year)—although this rate of TFP growth is lower than the world average. The slowest rate of productivity growth in the industrialized countries' agricultural sector is for ruminants (0.71%/year). Even so, the ruminants' TFP growth rate over this 40-year period is higher than for all other regions, with the exception of the PRC.

B. Forecasts of Agricultural Productivity Growth

In constructing the forecasts of future productivity levels in agriculture, the paper departs in two significant ways from the current “state of the art” in agricultural commodity forecasts (Rosegrant et al. 2001, USDA 2005, OECD-FAO 2005). First of all, rather than forecasting *partial* factor productivity (e.g., output per hectare), TFP is forecast based on historical measures of TFP by

eight major regions of the world previously identified. Second, rather than simply extrapolating based on past trends, we recognize that there are two important contributors to historical productivity growth—technical change and technical efficiency, and these may behave quite differently over the forecast period. While there is no economic reason to argue against continued outward movement in the technology frontier in line with historical trends, the process of “catching up” to the frontier, in which some developing countries are currently engaged, is unlikely to continue unabated. The simple reason for this is that in cases such as the PRC’s “catching up” to the frontier in ruminant livestock production, they will eventually reach the frontier. At that point, the PRC’s productivity growth may be expected to slow down, with future growth constrained by outward movement in the technological frontier.

To project changes in the technical efficiency component of TFP growth, technological catch-up can be modeled as a diffusion process of new technologies, where the cumulative adoption path follows an S-shaped curve (Griliches 1957, Jarvis 1981). This curve denotes that efficiency change at the beginning changes slowly because new technologies take some time to be adopted. As technology becomes more widely accepted, a period of rapid growth follows until it slows down again and reaches a stable ceiling. In this case, efficiency levels for all regions is assumed to eventually reach the production possibility frontier and become fully efficient. Nin et al. (2004) is followed in modeling this adoption path using a logistic functional form to capture the catching up process for each of the countries/regions in the sample. As in Nin et al. (2004), before estimating the logistic function, Chow tests of structural breaks of the efficiency time series are performed. With this, historical changes in the efficiency series, which may cause possible differences in the intercept or the slope or both (see Ludena et al. 2006 for more details), are accounted for.

The rate of technical change in future TFP growth must also be projected. Here, it is simply assumed that countries grow at their historical trends. However, in the case of those regions with average growth rates higher than industrialized countries, the rate of future technical change is assumed to erode (linearly) over time, so that it eventually falls to the rich country growth rate. In particular, it is assumed that, after 20 years, the regions with initial rates of technical change above the industrialized countries will be growing at the same rate as industrialized countries (otherwise, they would eventually exceed the productivity levels in the developed countries).

The lower portion of each regional panel in Table 3 contains TFP, efficiency, and technical change projections for each subsector in each region over the projection period 1997–2025. The first thing to note is that the weighted average for World is higher in the projection period than in the historical period for TFP (1.43%/year vs. 0.94%/year), and for all three agricultural subsectors. When compared to the component parts of TFP, this difference is found entirely due to the projected increase in technical efficiency over the next two decades. This reflects a continuation of the improvements in efficiency observed between the 1980s and the 1990s. On the other hand, technical change is actually projected to be lower in the projection period, despite the fact that projection is based on historical trends. This difference between the historical period and the projection period is due to the anticipated slowing down of the very high rate of technological change in a few key developing countries in the future as discussed in the preceding paragraph.

Moving to the left of the top panel in Table 3 shows which subsectors contribute the most to this higher rate of average TFP growth for agriculture. The overall average TFP growth rate for crops and ruminants is lower in the historical and projection period, with nonruminants showing much higher TFP growth rates over the projection period. And, as anticipated above, this is fueled by high rates of “catching up” as predicted by the logistic model of technical efficiency.

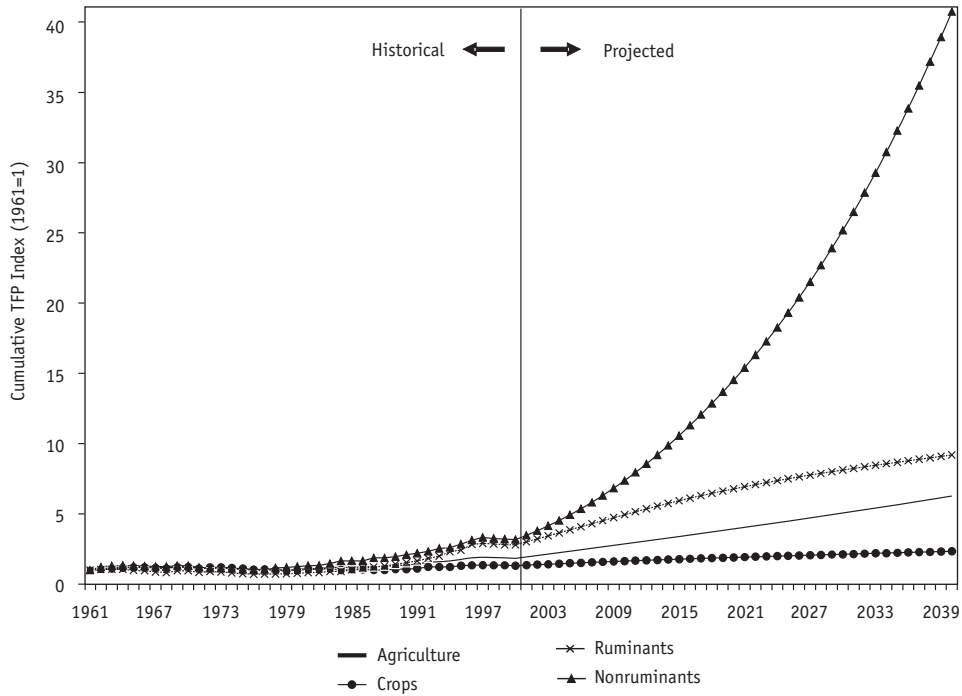
The PRC’s TFP growth rate in the projection period is higher for all subsectors than for the historical period. However, with the exception of nonruminants, TFP growth for the next two decades is lower than that for the decade of the 1990s. Again, the main difference is the projected rate of growth in technical efficiency, which is extremely high for ruminants (a very small sector in the PRC, accounting for just 7% of total output). It is also high for nonruminants where TFP growth over the past two decades has been in excess of 4%, as the PRC makes the transition from backyard pig and poultry production systems to modern, industrial production.

In East and Southeast Asia, the projected weighted average productivity growth for all three subsectors is 0.09%, with higher productivity growth rates (3.23%) for nonruminants. The projections for South Asia, based on the entire developing Asia region, are higher than the historical estimates, with the highest growth rates for nonruminant livestock. In the case of the Economies in Transition region, much of the historical TFP growth was attributed to technological progress. For Middle East and North Africa, TFP for all three subsectors is projected to be 0.22%, with higher growth in crops (0.03%). In Sub-Saharan Africa, average agricultural TFP growth over the next two decades is projected to be 0.85%, fueled by both outward shifts in the frontier and improved efficiency. For Latin America, average agricultural TFP growth is projected to be higher than historically, with the difference largely driven by livestock productivity growth. Finally, TFP forecasts for Industrialized Countries are a bit lower than in the historical period (0.87% vs. 1.19% in the historical period) as a consequence of a slower rate of technical efficiency growth. All three agricultural sectors show somewhat lower TFP growth in the industrialized countries over the forecast period.

A useful way of summarizing the TFP information in Table 3 is via line graphs. This is done for the three Asian regions in Figures 4–6, which display the cumulative Malmquist TFP index for each subsector, as well as for the overall average, for both the historical and projected periods. The first thing to note from these figures is the heterogeneity across subsectors in each region. Taking an average of the subsectors, or simply measuring TFP at the level of aggregate agriculture, is highly misleading if one is attempting to understand changes in commodity supplies or input use over time. These figures also permit one, in the historical period, to more readily identify the impact of economic reforms such as those in PRC in the late 1970s.

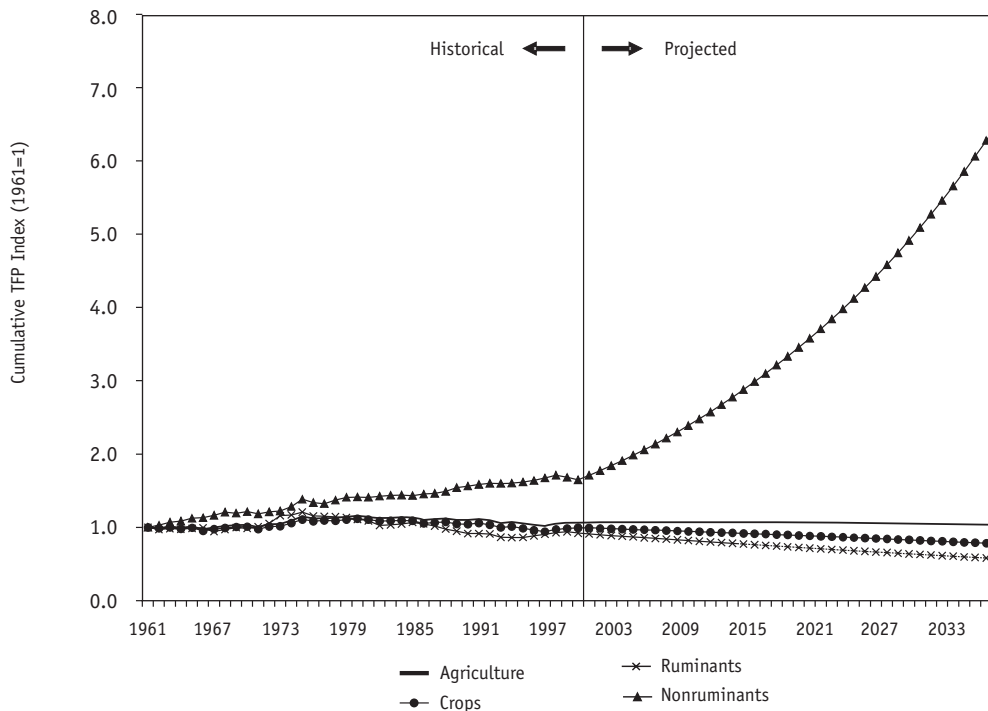
These figures also underscore the dynamism of the nonruminant livestock sector. In the past two decades, TFP growth rates in the PRC have been extremely high, with South Asia not far behind. If this “catching up” process continues in the next two decades, productivity in many parts of the world will reach that in the industrialized countries. Of course, not all the TFP projections are positive. With the exception of nonruminants, East and South East Asian TFP falls over the projection period. Without significant investments in research and extension infrastructure, it is unlikely that this trend can be reversed.

FIGURE 4
 CUMULATIVE MALMQUIST INDICES FOR CROPS, RUMINANTS, AND NONRUMINANTS IN THE PRC, 1961–2040



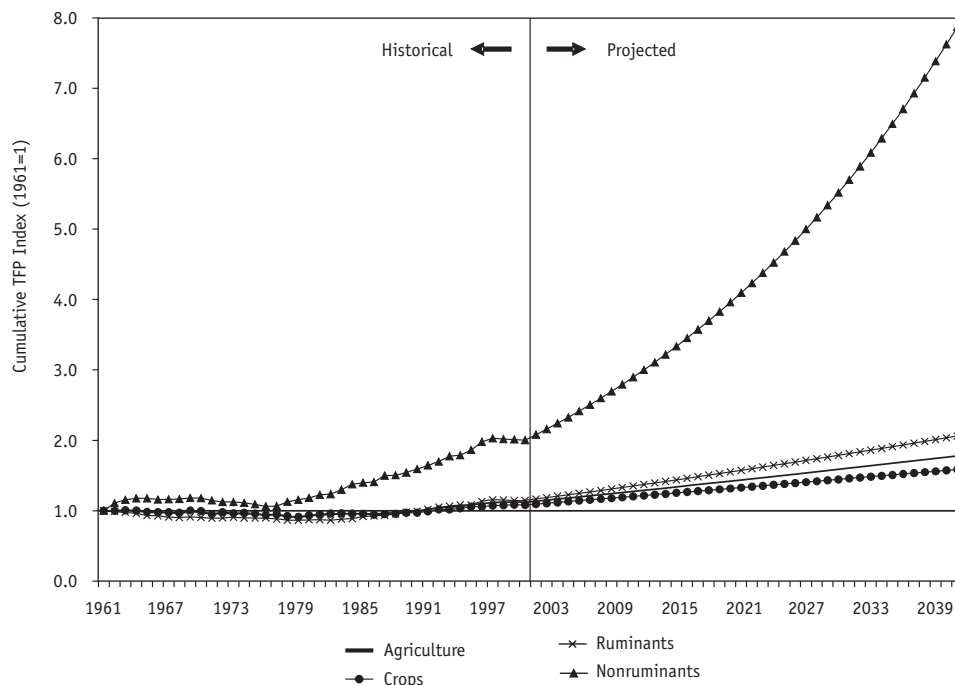
Source: Ludena et al. (2006.)

FIGURE 5
 CUMULATIVE MALMQUIST INDICES FOR CROPS, RUMINANTS, AND NONRUMINANTS IN EAST AND SOUTHEAST ASIA, 1961–2040



Source: Ludena et al. (2006.)

FIGURE 6
CUMULATIVE MALMQUIST INDICES FOR CROPS, RUMINANTS, AND NONRUMINANTS IN SOUTH ASIA, 1961–2040



Source: Ludena et al. (2006.)

C. TFP Growth in Manufacturing and Services

As noted previously, while the focus in this paper is on food and agriculture, the evolution of TFP in the nonfarm sectors is also critical both from the supply side (evolving comparative advantage) and from the demand side (fueling income growth). In order to construct these forecasts, the paper draws heavily on the work of Kets and Lejour (2003) as well as the economic growth forecasts of the World Bank.

In their historical study of TFP by sector in the OECD, Kets and Lejour (2003) compute the increase in output per unit of value-added for agriculture, manufacturing, services, and raw materials over the period 1970–1990, assuming a Cobb-Douglas production function. (Note that the agricultural TFP growth rates discussed above also reflect intermediate inputs, in addition to value-added.) Simple average growth rates reported in Kets and Lejour (2003)—preferable over weighted average due to the high weight/questionable nature of some of the US estimates—are range from 0.42%/year for services to 2.68%/year for agriculture, with the economywide average at 0.87%/year. Their disaggregated estimates for manufactures and services show considerable variation particularly in services, with communications (3.38%/year) and transportation (1.38%/year) being above-average. Using these estimates as a guide, the ratio of TFP growth in agriculture, manufacturing, and services is computed to the economywide average. These are reported in Table 4, and, with the exception of agriculture, these differentials are applied to the underlying labor productivity growth rates reported in Table 2 (to be discussed below). It should be noted that while Kets and Lejour (2003) measured productivity growth rates over all of value-added (labor and capital), in economic growth

TABLE 4
LABOR PRODUCTIVITY DIFFERENTIALS: SECTORAL VALUE-ADDED PRODUCTIVITY GROWTH
RELATIVE TO THE ECONOMYWIDE AVERAGE

SECTOR	ANNUAL GROWTH (PERCENT)
Agriculture	3.08
Energy Extraction	0.78
Manufactures	2.24
Services (general)	0.48
Transportation and Communications	2.24

Note: Agriculture differential is not used in this study.
Source: Kets and Lejour (2003).

models (their model included) it is customary to implement productivity growth as applying to labor productivity only.⁵ Thus, productivity growth for the nonagricultural sectors is expressed in terms of labor productivity growth only (see Table 4).

Table 3 carries independent estimates for agriculture of the rate of technical change worldwide. These are used directly in the model, rather than treated in the same manner as TFP for the other sectors, since the measurement concepts in the Ludena et al. (2006) TFP study are quite different from those in the Kets and Lejour (2003) study. The former considers the productivity of all inputs, not just value-added. Thus agriculture is treated differently here.

The paper wrestles with the question of overall productivity growth in agriculture, relative to the rate of population and income growth. History suggests that, despite occasional spikes in the price of farm commodities, the long-run trend for these products is downward. In the baseline, agricultural productivity growth is augmented *in all regions* by a common factor, *tfp-agriculture*, which is chosen in order to ensure that crops prices fall at the same rate as the average price of all traded goods. Were this not the case, even with the relatively high rates of TFP growth shown in Table 3, farm prices would rise by an implausible amount over the projection period. Despite targeting overall TFP growth in this way, the regional and subsector variations evident in Table 3 result in considerable variation in prices across subsectors and across regions in the baseline forecast.

Appendix Table A2.2 shows the overall growth rates for labor productivity in the 11 regions in the model. These growth rates are reported in the third column of Table 2, and they are the base growth rate upon which the productivity growth differentials for the nonagricultural sectors in Table 4 are applied. For example, the annual rate of labor productivity growth in North America is $2.24 * 1.0 = 2.24\%$ in manufactures and in transportation and communications, but just $0.78 * 1.0 = 0.78$ in energy extraction. In ASEAN, by contrast, the labor productivity growth rate in manufactures is assumed to be $2.24 * 2 = 4.48\%/year$.

⁵ This is because the availability of capital is naturally enhanced through investment and capital accumulation.

V. IMPLICATIONS FOR INTERNATIONAL INVESTMENT AND ECONOMIC GROWTH

Having specified the growth rates for exogenous endowments and technological progress, the model can now predict international capital accumulation and economic growth. In these projections, a modified version of the Dynamic GTAP model (Ianchovichina and McDougall 2001), nick-named GTAP-Dyn., is used. This is a recursive dynamic model built upon the static GTAP model, which adds a sophisticated specification of international capital mobility, in addition to tracking foreign and domestic ownership of capital stock. The latter feature permits the model to track foreign income payments, which become an increasingly important feature of the balance of payments over the long run. The model permits capital to be imperfectly mobile in the near term, but risk-adjusted rates of return converge in the long run, when capital is perfectly mobile. The speed of convergence in rates of return in the model of 9% per year is based on the econometric work of Golub (2006) for a sample of OECD countries.⁶

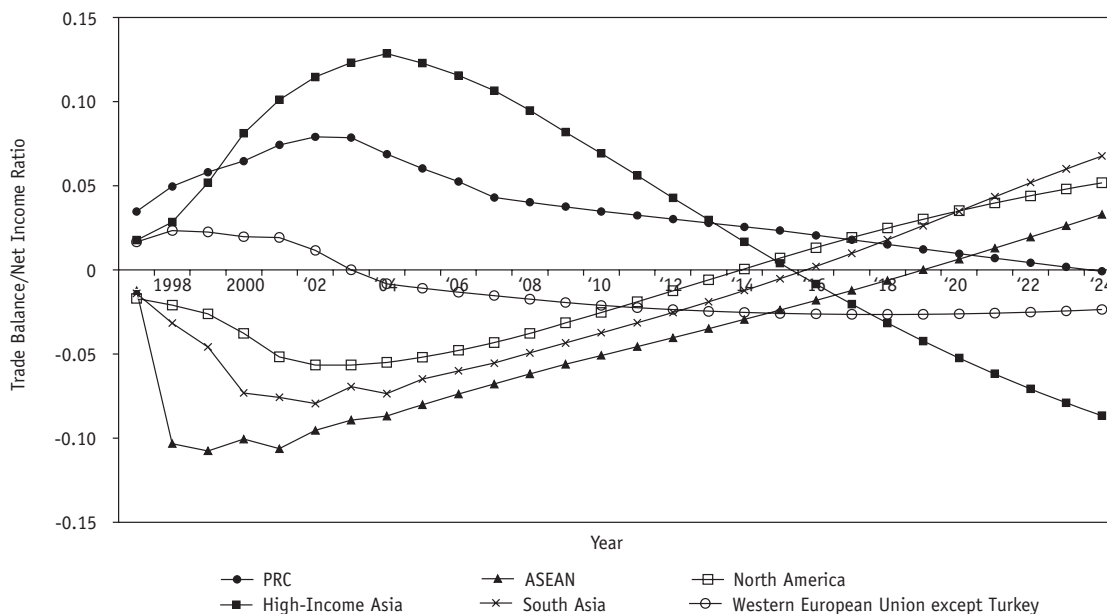
Based on the newly parameterized GTAP-Dyn model, the expected rate of capital accumulation, and hence GDP in each region over the baseline period, can be estimated. These are reported in the fourth and fifth columns of Table 2, under the heading “endogenous variables.” The highest rate of cumulative capital accumulation is in South Asia, where labor force growth and productivity growth are both very high. The PRC, with higher productivity growth but lesser labor force growth, has a lower rate of total capital accumulation. This contrasts sharply with the World Bank projections for capital accumulation in the PRC (second to last column of Table 2), which are much higher for the PRC and only half for South Asia. The GTAP-Dyn model predicts a slowing of investment in the PRC as growth in the labor force eases later in the forecast period.

As a consequence of the slower capital accumulation, the projected GDP growth in the PRC in the baseline is also lower than the World Bank forecasts, although not that much lower. On the other hand, cumulative GDP forecast for South Asia is considerably higher (413% vs. 326% over this 28-year projection period). The GTAP-Dyn based GDP projections are lower for High-Income Asia, which experiences only modest labor force growth, and higher than the World Bank’s projection for ASEAN.

Based on the paper’s projections for net national savings and investment as well as foreign income payments (which are faithfully tracked by GTAP-Dyn over the projections period), a baseline path for the trade balance is obtained for each region. Trade balance is divided by net national income, and the ratio is plotted in Figure 7 for the four Asian economies. Over the historical part of the projection period, the PRC and High-Income Asia have been running trade surpluses, while South Asia and ASEAN have been running trade deficits. The projections suggest that these roles will be reversed by the end of the projection period, due to a slowing of savings in the PRC, and due to the increased importance of increased income payments on foreign assets that come to dominate the balance of payments for High-Income Asia. Indeed, by 2016, the latter region is projected to move into trade deficit as a consequence. In the case of South Asia, the opposite is true. Current investment inflows increase the stock of foreign-owned capital in the region, and eventually, foreign income payments on these investments force South Asia to run a trade surplus.

⁶ For purposes of this study, the GTAP-Dyn model has been modified to incorporate the AIDADS demand system (An Implicit Directly Additive Demand System) discussed above. In addition, the sectoral production functions have been altered to accommodate the differentiation of land use by AEZ, following the work of Golub (2006).

FIGURE 7
 EVOLUTION OF TRADE BALANCE RELATIVE TO NET NATIONAL INCOME, 1961–2040



Source: Authors' projections.

VI. IMPLICATIONS FOR STRUCTURAL CHANGE AND FUTURE PATTERNS OF TRADE

Table 5 provides a useful overview of structural change in the baseline scenario. Individual sectors have been aggregated into five broad categories: Agriculture, Food, Manufactures, Services, and Natural Resources. For each of these sectors, change in composition of output (percent change in sectoral output/real GDP) and consumption (percent change in sectoral consumption/real GDP) are reported. The first thing to note is that the share of the food sector in overall real production and consumption falls sharply across the board,⁷ with consumption falling more rapidly than production in the economies of Australia and New Zealand, the Americas, and Western Europe. On the other hand, the share of production falls more sharply in Asia, Economies in Transition, and Middle East and North Africa. On the other hand, manufactures' share in real output rises strongly in the PRC and South Asia. This share also rises in Sub-Saharan Africa and North America—the latter being somewhat surprising, given its recent downward trend in North America. This rise is driven by a real depreciation in North America (i.e., in the United States), which is forced run a trade surplus by the end of the projection period in order to repay foreign investors. Manufactures' share in real consumption rises in many regions, with the strongest increases arising in the PRC, High-Income Asia, Economies in Transition, and Middle East and North Africa.

⁷ Initially, agricultural TFP growth in High-Income Asia is based on a sample of high-income economies, including North America and Western Europe. This likely leads to an overstatement of TFP growth particularly in the crop sector. For this reason, annual TFP growth rate in crops in High-Income Asia is set equal to annual average TFP growth rate in crops in ASEAN.

Table 5 also shows that services' share in real output rises in all regions, except North America and Economies in Transition, with the rise being particularly sharp in South Asia, followed by ASEAN. The slight decline in North American services output is driven by the nontraded service sectors and follows from the strong expansion in the more heavily traded sectors—again due to the requirement for the region to run a trade surplus by the end of the projections period. Natural resources share in output and consumption is driven strongly by the rapidly rising prices for these products (fisheries, forestry, and petroleum output) over the baseline period (see below for details). This constrains real consumption relative to real GDP, and results in an increase in output in some of the regions. The strong increase in petroleum output in the High-Income Asia region results from massive capital investment. Unfortunately, the model does not take into account reserves and the potential for their development, and this outcome does not appear to be realistic.

TABLE 5
RELATIVE SUPPLY AND DEMAND: CUMULATIVE 1997–2025 CHANGE (PERCENT)

SECTOR	RATIO	ANZ	PRC	HYASIA	ASEAN	SASIA	NAM	LAM	WEU	EIT	MENA	SSA
Agriculture	QO/QGDP	-18	-53	-40	-69	-61	-14	14	-16	-30	-40	-43
	QP/QGDP	-52	-48	-25	-58	-57	-45	-43	-30	-14	-8	-43
Processed Food	QO/QGDP	-34	-52	-41	-70	-62	0	-11	-14	-22	-43	-42
	QP/QGDP	-40	-25	-7	-52	-61	-23	-42	-24	-4	7	-35
Manufacturing	QO/QGDP	11	37	-35	4	60	22	5	-9	-4	-6	28
	QP/QGDP	-8	99	46	-15	6	-10	-22	8	23	28	-4
Services	QO/QGDP	1	1	4	30	32	-4	8	3	-5	11	12
	QP/QGDP	-10	43	29	-4	16	-16	-16	4	4	28	-7
Natural Resources	QO/QGDP	-13	-28	232	-49	-30	-4	-30	14	21	-14	-29
	QP/QGDP	-41	-5	15	-57	-28	-32	-44	-35	2	-10	-34

ANZ means Australia and New Zealand.

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PRC means People's Republic of China.

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SAsia means South Asia.

SSA means Sub-Saharan Africa.

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Table 6 reports the change in the trade balance (in billion US dollars) over the baseline period. The first thing to look at in this table is the row labeled "total", which reports the change in trade balance from 1997 to 2025, for each region in the model. The sum of these totals equals zero, as must be the case in a global model (zero world trade balance). As noted previously, these regional trade balances are largely driven by the changes in savings, investment, and foreign income payments. High-Income Asia moves from trade surplus at the beginning of the period to trade deficit at the end due to declining savings and rising foreign income payments from abroad. North America moves in the opposite direction by a comparable magnitude, as it is required to move from trade deficit to surplus. As a consequence of these aggregates, the sectoral trade balances for High-Income Asia deteriorate for nearly all sectors, while those for North America improve for all sectors except natural resources.

TABLE 6
CHANGE IN TRADE BALANCE, BY SECTOR (US\$ BILLIONS)

SECTOR	ANZ	PRC	HYASIA	ASEAN	SASIA	NAM	LAM	WEU	EIT	MENA	SSA	TOTAL
Agriculture	27.1	-224.1	-18.3	-47.7	-97.2	99.2	144.6	75.9	-5.2	-37.6	24.5	-58.8
Processed Food	9.3	-198.2	-209.9	-70.2	-13.6	326.6	70.0	145.7	-21.7	-95.2	-17.6	-74.9
Manufacturing	-24.5	990.3	-799.0	-146.1	261.3	439.3	-120.3	-668.2	-105.4	-287.9	-17.1	-477.6
Transportation and Communications	8.0	187.4	-13.0	-22.6	95.9	169.1	7.9	87.5	209.3	-9.8	-12.1	707.7
Other Services	41.7	-320.4	-368.8	471.3	152.0	231.3	236.0	-120.8	-304.3	-111.4	72.1	-21.3
Natural Resources	-1.6	-483.1	154.2	-112.9	-234.6	-278.2	1.0	17.2	222.2	594.6	46.0	-75.1
Total	59.9	-48.1	-1254.8	71.9	163.8	987.4	339.2	-462.7	-5.1	52.8	95.8	0.0

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SSA means Sub-Saharan Africa.

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Turning to the column labeled "Total" in Table 6, we note that the row sums for the change in world sectoral trade balances are not equal to zero. They are negative for goods trade and positive for transport services. This is because the trade balance is evaluated by deducting *freight-on-board* exports from cost-insurance-freight imports. The difference comprises the international trade and transport margins that are recorded as services exports, hence giving rise to a positive row sum for this sector, which is separated from other services in Table 6.

Now consider individual entries in Table 6 on a sector-by-sector basis. The entries in the second column of this table show that the PRC is expected to increase its annual net imports of farm and food products by about \$425 billion by the end of the projection period. The largest portion of this increase comes in the imports of (land-intensive) agricultural products (crops and ruminant meats), while actually increasing its net exports of nonruminant meats for which it has a continued high rate of TFP growth, and which is unconstrained by land availability. ASEAN and South Asia also increase their net imports of total food products, with the net change in their food trade balance amounting to more than \$230 billion, as compared to the 1997 benchmark. When combined, this result is a very substantial net export requirement from the rest of the world.

The global imbalance in food trade caused by the growth in developing Asia net imports is made up by a surplus from the rest of the world. The largest share of this increase is supplied by North America and Europe—two regions with high rates of technological progress in agriculture, low population growth rates, relatively low per capita income growth rates, low income elasticities of demand for food, and strong positions in the production and export of high value-added food products. The importance of trade in processed food products for these two regions may be seen by comparing the agriculture and food rows. In the case of Western Europe, the increase in net processed food exports is double that for agriculture. In North America, it is more than three times as large. Australia and New Zealand and Latin America also play an important role in the increase in net exports of food products to the world market.

The global manufacturing trade balance is dominated by the PRC, which shows a net increase of \$990.3 billion over the projection period. North America and South Asia also show increases in

net exports of manufactures. In North America, this is driven by the need to improve its overall trade balance by nearly \$1 trillion by 2025. The largest negative changes in the manufactures trade balance are for High-Income Asia and Western Europe, both of which are expected to show strong deterioration in their aggregate trade balance by the end of the projections period (e.g., recall Figure 7).

Most of the economies show a positive trade balance in transport and communications services. This is because increased global trade requires the increased use of trade and transport services of around \$707.7 billion annually by the end of the projection period. Exceptions are HYAsia and ASEAN, as well as Middle East and North Africa, and Sub-Saharan Africa. Net exports of other services rise for the Americas, ASEAN, Australia and New Zealand, South Asia, and Sub-Saharan Africa.

Finally, in the case of natural resources (dominated by petroleum), the big story is the strong increase in net imports by the PRC, and, to a lesser degree, South Asia and North America. This change is largely accommodated by increased net exports of natural resource-based products from the Middle East and North Africa, Russia and the former Soviet Republics, and to a lesser degree, Sub-Saharan Africa.

In addition to viewing these changes through the trade balance, we can also analyze them through the regional self-sufficiency ratios, defined simply as the ratio of the value of production, at market prices, to the value of consumption, again at market prices. Where this ratio is equal one, the region is deemed to be “self-sufficient” even though it is likely that they are exporting and importing the product in question, due to the prevalence of intra-industry trade, as well as the strong taste for variety in most regions. When the ratio is in excess of one, this means that the value of what they are producing exceeds the value of what they are consuming in this particular sector. When the ratio is less than one, it means that the region consumes more than it produces, measured in values at domestic market prices.

Table 7 reports the self-sufficiency ratios for the years 1997 and 2025 for each sector/region in the model. Not surprisingly, there are some dramatic changes in these values. The PRC’s self-sufficiency ratio falls sharply for all food products, except nonruminants and processed nonruminants. The same is true for most of Asia. On the other hand, ANZ, North America, and Western Europe (except nonruminants and nonruminant products) become far more than self-sufficient in food products, with the exception of nonruminants, where rapid productivity growth in the developing countries (including the PRC) results in increased self-sufficiency ratios. Such dramatic changes in regional self-sufficiency ratios for food will only occur in the absence of substantial changes in trade policy. However, in the absence of WTO disciplines, we can expect rising protection in Asia, while budget constraints may eventually translate into reduced farm subsidies in North America and Western Europe. Both of these factors would lessen the shift portrayed in this baseline.

In the case of textiles and apparel, the PRC and South Asia strengthen their positions as surplus producers, with all other regions (except EIT) reducing their self-sufficiency ratios. In the case of other manufactures, the PRC and South Asia also strengthen their positions, while North America and Europe reverse positions, with the former region now becoming more than self-sufficient, and Western Europe falling below self-sufficiency, as it experiences a real appreciation and an increased trade deficit. The PRC and South Asia also experience big boosts in transportation and communications services, as their economies grow rapidly over this period, and these services are required for increased international trade.

TABLE 7
SELF-SUFFICIENCY RATIOS, 1997 AND 2025

SELF-SUFFICIENCY RATIO	YEAR	ANZ	PRC	HYASIA	ASEAN	SASIA	NAM	LAM	WEU	EIT	MENA	SSA
1. Crops	1997	1.43	0.99	0.79	0.95	1.01	1.12	1.07	0.80	0.96	0.87	1.08
	2025	2.46	0.71	0.76	0.74	0.84	1.42	1.27	1.29	1.02	0.78	1.21
2. Ruminants	1997	1.05	1.01	0.97	0.92	1.00	1.00	1.00	0.99	1.01	0.97	1.00
	2025	1.17	0.98	1.00	0.66	1.00	1.01	1.06	1.01	1.03	0.82	1.00
3. Nonruminants	1997	1.45	1.01	0.87	1.00	1.00	1.06	1.00	0.98	1.00	0.94	1.01
	2025	0.81	1.03	0.62	0.90	0.92	0.43	6.08	0.25	0.58	0.12	0.52
4. Processed Ruminants	1997	1.08	1.01	0.70	1.01	1.00	1.05	1.02	1.00	0.89	0.53	0.94
	2025	2.06	0.68	0.77	0.74	0.67	1.03	1.09	1.06	0.90	0.45	0.93
5. Processed Nonruminants	1997	1.08	1.01	0.70	1.01	1.00	1.05	1.02	1.00	0.89	0.53	0.94
	2025	0.93	2.08	0.36	0.71	0.76	0.98	1.17	0.75	0.71	0.25	0.81
6. Processed Food	1997	1.05	0.96	0.90	1.09	1.01	0.98	1.06	1.00	0.90	0.84	0.97
	2025	1.09	0.51	0.64	0.68	0.86	1.40	1.14	1.18	0.92	0.54	0.91
7. Textiles and Apparel	1997	0.93	1.21	0.99	1.23	1.32	0.75	1.01	0.87	0.86	0.96	0.93
	2025	0.64	1.26	0.66	1.09	1.35	0.57	0.92	0.47	0.87	0.83	0.77
8. Manufactures	1997	0.85	0.97	1.08	0.90	0.87	0.95	0.91	1.03	0.89	0.72	0.87
	2025	0.90	1.10	0.88	0.88	1.09	1.05	0.92	0.95	0.87	0.64	0.95
9. Wholesale/Retail Trade	1997	1.00	1.00	1.01	0.98	1.00	1.00	0.99	1.00	0.99	0.99	0.94
	2025	1.01	0.88	0.99	1.58	1.07	1.00	1.06	1.00	0.94	0.98	1.00
10. Transportation and Communications	1997	1.02	1.03	1.03	1.11	1.02	1.06	0.99	1.07	1.14	1.05	0.98
	2025	1.06	1.27	1.01	0.96	1.26	1.10	1.00	1.09	1.61	1.00	0.95
11. Financial Services	1997	0.99	0.98	0.99	1.04	1.01	1.01	0.98	1.00	0.96	0.96	0.97
	2025	0.98	0.94	0.95	1.48	1.16	1.01	1.19	0.97	0.77	0.83	1.06
12. Housing and Other Services	1997	1.01	0.99	0.99	0.99	1.00	1.01	0.99	1.00	1.00	0.96	0.99
	2025	1.01	0.98	0.98	1.03	1.18	1.02	1.04	1.00	0.95	0.96	1.03
13. Forestry	1997	1.23	0.94	0.60	1.11	0.97	1.06	1.03	0.90	1.20	0.96	1.25
	2025	1.33	0.73	0.87	0.79	0.82	1.08	1.50	1.39	1.57	0.90	1.33
14. Fishery	1997	1.21	1.02	0.89	1.03	1.01	0.93	1.05	0.98	1.05	1.03	1.04
	2025	1.19	0.89	1.35	1.08	1.02	0.64	0.82	1.12	1.18	0.97	0.98
15. Utilities	1997	1.20	1.02	0.94	1.09	0.98	1.00	0.97	0.98	1.03	1.05	1.04
	2025	1.50	0.94	0.87	1.15	1.02	1.04	1.08	1.03	0.85	0.90	1.16
16. Petroleum	1997	0.86	0.90	0.59	0.85	0.60	0.82	1.22	0.76	1.16	2.20	1.66
	2025	0.87	0.73	0.98	0.69	0.47	0.84	1.09	0.90	1.33	2.21	1.29
17. Construction	1997	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99	1.01	1.00
	2025	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	0.97	1.01	1.01

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The change in economic structure portrayed in Tables 5–7 are driven by a combination of supply and demand forces. The forces driving the demand side were discussed at length above. However, on the supply side, there are also strong forces at work. Strong growth in unskilled labor in an economy favors expansion of labor-intensive activities—the so-called Rybczynski Effect. Similarly expansion of the capital stock favors growth in the capital intensive sectors. Of course, the question of where the additional endowments end up being employed also depends on the current employment rates for these factors of production. Table 8 sheds some light on this issue by reporting the cumulative expansion in capital and labor endowments over the projection period, and where these factors end up being employed in 2025. For example, in the case of the PRC, the capital stock expands more than five-fold over the 1997–2025 period (553%). The capital entries in the PRC column indicate that the majority of capital is absorbed in the services sector where capital expands by 993% over the projection period. This is followed by natural resource production, manufactures, and finally, the food sector (51% growth in capital usage). Perusal of Table 8 indicates that in most economies the highest rates of employment increase are in services and natural resources. However, the latter is a relatively small sector and the increase in labor and capital in these sectors is in response to dramatic price increases (see below). On the other hand, the food and agriculture sector continues to shed at least some factors of production in many regions.

TABLE 8
CHANGE IN FACTOR USAGE BY SECTOR AS A PERCENT OF 1997 LEVELS

SECTOR		ANZ	PRC	HYASIA	ASEAN	SASIA	NAM	LAM	WEU	EIT	MENA	SSA
Food	Unskilled	25	-2	-32	-18	31	35	37	7	-26	8	31
	Skilled	-15	-8	-43	-14	-10	22	99	-12	-40	14	30
	Capital	76	51	-29	38	88	149	120	45	-4	9	100
Manufacturing	Unskilled	47	-12	-40	72	84	51	55	-1	-47	34	135
	Skilled	19	28	-37	222	201	36	240	-16	-50	89	176
	Capital	193	202	-35	472	604	217	322	44	-28	48	408
Services	Unskilled	57	68	33	91	63	47	38	39	19	85	93
	Skilled	28	224	41	269	203	26	194	18	24	182	137
	Capital	253	993	74	599	852	235	278	125	127	134	391
Natural Resources	Unskilled	122	120	231	151	208	168	148	109	101	150	179
	Skilled	142	204	420	233	328	185	223	144	106	184	201
	Capital	253	851	440	261	403	311	231	207	317	230	272
Total	Unskilled	55	26	16	68	66	49	43	26	-2	69	96
	Skilled	26	173	26	260	222	28	206	10	13	178	146
	Capital	250	553	51	534	731	239	286	114	96	126	376

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Source: Authors' simulations.

Given the differential rates of factor accumulation, as well as differential productivity growth rates, it is hardly surprising that changes in factor prices vary widely across factors and across regions over the projection period (Table 9). For example, in ANZ, unskilled labor is projected to grow at twice the rate of skilled labor, and the relatively stronger growth in skilled wages reflects this fact. On the other hand, in the PRC, unskilled labor grows very slowly, and skilled labor quite rapidly, so unskilled wages grow much faster in the baseline. Of course, this analysis abstracts from the pool of underemployed, unskilled labor in the rural PRC that might conceivably serve as a reservoir for additional workers, at least in the medium term. Perhaps more importantly, we assume in the baseline that productivity growth rates are equal for both unskilled and skilled labor. However, this is unlikely to be true. We expect future technologies to favor skilled labor, and this will serve to dampen relative wage growth for unskilled labor in most regions.

TABLE 9
CUMULATIVE CHANGES IN FACTOR PRICES OVER THE BASELINE PERIOD (PERCENT)

FACTOR	ANZ	PRC	HYASIA	ASEAN	SASIA	NAM	LAM	WEU	EIT	MENA	SSA
Unskilled	34	241	36	36	47	43	40	26	143	27	18
Skilled	62	149	30	-17	-1	58	-25	47	154	-4	4
Capital	-31	-33	8	-50	-63	-29	-37	-17	23	0	-40

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Note: Price changes are relative to the global factor price index.

The other key factor market assumption is that of international capital mobility. We assume that, in the long run, rates of return to capital converge. This drives much of the long-run change in capital returns, which also fall on average, relative to wages, as a result of capital accumulation. We see such declines in all regions, except for High-Income Asia and Economies in Transition. Labor, on the other hand, is assumed to be immobile internationally. This is somewhat of an extreme assumption. However, it appears unlikely that sufficient mobility will be permitted over this baseline period to have a substantial impact on international wage differentials.

The final piece of this global baseline that needs to be discussed is the change in world prices by sector (Table 10). Recall from the discussion on TFP projections that the sectoral/regional agricultural productivity growth rates are adjusted by a single, global factor to ensure stable crops prices, relative to other traded goods, hence the zero in the first row of Table 10. Relatively higher productivity growth for livestock products—particularly nonruminants in developing countries—results in a sharp decline in prices for those products, while ruminant prices fall by a modest amount. Prices of textiles and apparel, manufactures, and services also fall, relative to the world price index. On the other hand, the prices of natural resource-based products—particularly fisheries and petroleum—rise very sharply due to the presence of a specific natural resource endowment and relatively slower productivity growth rates than those in agriculture and manufacturing.

TABLE 10
RELATIVE COMMODITY PRICES FOR BASELINE SCENARIO

SECTOR	BASELINE
Crops	0.00
Ruminants	-10.33
Nonruminants	-72.14
Processed Ruminants	-11.19
Processed Nonruminants	-44.53
Processed Food	-1.98
Textiles and Apparel	-24.29
Manufactures	-11.52
Wholesale/Retail Trade	-4.50
Transport and Communications	-7.22
Financial Services	-9.45
Housing and Other Services	-1.67
Forestry	29.70
Fisheries	650.62
Utilities	6.41
Petroleum	158.56
Construction	1.93

Note: Price changes are relative to the index of world commodity and services trade. Baseline world price of crops is forced to move with the index of world commodity and service trade.

Source: Authors' estimates.

Table 11 pulls together the implications of the entire baseline scenario for poverty in the developing Asian regions. This begins by evaluating the change in unskilled wages, relative to the cost of living at the poverty line. The latter is evaluated at the poverty level of utility (recall Figure 1 and the associated discussion), which involves a very different consumption bundle than that consumed by the average, per capita household. Due to the relatively greater dependence of poor households on commodity consumption, their cost of living tends to rise faster than the overall consumer price index. As a consequence of this, and relatively modest growth in unskilled wage growth in South Asia and ASEAN, real income growth at the poverty line is also rather modest—about 30% over this period. We use the World Bank's regional poverty elasticities in the model, and this income growth gives rise to a decline in the poverty headcount ratio over this period. Indeed, in the PRC, poverty is nearly eliminated. However, in South Asia, as a result of more modest growth in unskilled wages and lower poverty elasticity, the decline in the headcount ratio (17%) is insufficient

TABLE 11
INCOME AND HEADCOUNT CHANGES AT (\$2/DAY) POVERTY LINE: BASELINE

VARIABLE	PRC	SOUTH ASIA	ASEAN
Total Change in Real Income at Poverty Line	214	37	28
Poverty Elasticity	-1.63	-0.59	-2.17
Percentage Change in Headcount Poverty to Population Ratio	-82	-17	-41
Change in Headcount based on number of poor in 2001 (in billions)	-672	205	-51

Sources: Authors estimates. Poverty elasticities from The World Bank.

to overcome the rapid population growth in this region over the baseline period, and an increase in total poverty arises.

These poverty projections must be taken with a grain of salt. The poverty elasticities used here have been estimated based on recent history. They will surely change in the future. Also, the potential for existing surplus unskilled workers to depress wage growth is ignored. Of course, if the increased demand for unskilled labor is met by hiring unemployed workers at current wage rates, this too may have a very positive impact on poverty—assuming that these individuals come from poor households. A third assumption to bear in mind is that of skill-neutral labor productivity growth. If technical change favors skilled, relative to unskilled labor, the poverty outcome will be less optimistic. Finally, we have adjusted agricultural productivity growth rates upward worldwide to ensure stable crop prices. If this is not done, agricultural prices tend to rise strongly under the baseline, and this has a significantly adverse impact on the poor.

VII. ALTERNATIVE GROWTH SCENARIOS

As with any baseline scenario, there are many uncertainties. Nowhere is this more evident than for the TFP projections. Yet, as has been seen above, these are a major driver of economic growth and structural change. For this reason, we now turn to some alternative TFP scenarios, focusing on three key dimensions of the baseline. The first two pertain to growth rates in the fastest growing regions of the world—the PRC and South Asia—while the third variation on the baseline focuses on sector-specific productivity growth, in this case agricultural TFP in the ASEAN region. For the sake of conciseness as well as consistency, in each case, we will focus on the aggregate impact on the ASEAN region, and ultimately on the incidence of poverty in that region of the world.

A. Impact of Slower Growth in the PRC and South Asia

The first perturbation on the baseline considers the impact of a slowdown in the PRC. Specifically, we consider the possibility of nonagricultural labor productivity growth slowing from 5%/year to 1.5%/year—the growth rate in High-Income Asia. Slower growth in the PRC dampens the demand for primary products. Table 12 shows declines in the relative world prices of all agricultural and food products, as well as forestry and petroleum. Relative world prices for other products are higher as a result of slower growth in the PRC, particularly textiles and apparel products. This outcome is due to the PRC's influence on world supplies of these products. Slower labor productivity growth in nonagriculture translates into more modest increases in supply from the world's largest source of textiles and apparel.

TABLE 12
IMPACT OF ALTERNATIVE SCENARIOS ON RELATIVE WORLD PRICES:
CUMULATIVE DEVIATIONS FROM BASELINE IN 2025 (PERCENT)

COMMODITY	SCENARIO		
	PRC SLOWDOWN	SOUTH ASIA SLOWDOWN	ASEAN CROPS TFP
Crops	-11.78	-3.05	-2.22
Ruminants	-9.05	-1.82	-0.96
Nonruminants	-14.25	0.28	-0.25
Processed Ruminants	-2.92	-0.52	-0.43
Processed Nonruminants	-11.84	0.94	-0.06
Processed Food	-0.73	0.15	-0.21
Textiles and Apparel	5.50	0.54	-0.18
Manufactures	2.00	0.70	0.04
Wholesale/Retail Trade	1.98	0.70	0.25
Transport and Communications	1.06	0.64	0.08
Financial Services	2.01	0.86	0.22
Housing and Other Services	1.84	0.75	0.05
Forestry	-16.89	-7.16	-0.54
Fisheries	1.72	2.08	0.90
Utilities	1.16	0.59	0.09
Petroleum	-5.87	-2.31	0.12
Construction	1.26	0.68	0.04

Note: Both the baseline and alternative prices are measured relative to the index of world commodity and services trade.

Source: Authors' simulations.

The impact of this slowdown on other regions is felt primarily through the terms of trade. These are reported in the "Total" columns in Table 13. They are subsequently decomposed into the "world", "export", and "import" price components. The total terms of trade impacts for the PRC slowdown scenario are positive for the PRC (which reduces total exports) and South Asia. The positive impact on South Asia is quite striking, and it comes primarily through the world price effect, which measures the terms of trade impact, ignoring product differentiation. The fact is that the PRC and

South Asia are net exporters of the same types of products particularly textiles and apparel. Higher world prices for these products benefit South Asia. The opposite situation applies in the cases of Economies in Transition, Middle East and North Africa, and Sub-Saharan Africa, which are all net exporters of energy and natural resource-based products. Slower growth in the PRC depresses these prices (they grow less rapidly than under the baseline), thereby hurting these net exporters, whose terms of trade declines are again dominated by the world price effects.

TABLE 13
IMPACT OF ALTERNATIVE SCENARIOS ON TERMS OF TRADE:
CUMULATIVE DEVIATIONS FROM BASELINE FROM 1997 TO 2025 (PERCENT)

MERGE	PRC SLOWDOWN				SOUTH ASIA SLOWDOWN				FAST ASEAN TFP CROPS			
	TOTAL	WORLD	EXPORT	IMPORT	TOTAL	WORLD	EXPORT	IMPORT	TOTAL	WORLD	EXPORT	IMPORT
ANZ	-2.85	-1.82	-0.94	0.11	-0.83	-0.48	-0.38	-0.03	-0.32	-0.24	-0.09	0.00
PRC	6.82	-1.21	7.61	-0.48	0.61	0.79	-0.09	0.09	0.11	0.12	-0.01	0.00
HYAsia	-0.36	-0.48	0.64	0.52	0.29	0.03	0.30	0.04	0.14	0.13	-0.01	-0.02
ASEAN	-0.41	0.69	-0.83	0.26	0.14	0.26	-0.09	0.03	0.14	0.01	0.09	-0.04
SAsia	5.06	5.91	-0.50	0.30	5.54	1.87	3.20	-0.38	0.22	0.25	-0.04	-0.01
NAm	-1.42	-0.38	-0.76	0.29	-0.06	0.00	-0.08	-0.02	-0.13	-0.10	-0.03	0.00
LAm	-2.02	-1.14	-1.39	-0.51	-0.82	-0.70	-0.18	-0.06	-0.30	-0.25	-0.06	0.00
WEU	-0.61	-0.18	-0.59	-0.16	-0.11	-0.04	-0.09	-0.02	0.00	0.00	0.01	0.01
EIT	-2.00	-1.48	-0.75	-0.23	-0.80	-0.73	-0.07	0.00	0.03	0.03	0.01	0.01
MENA	-6.03	-4.42	-1.67	0.02	-2.65	-1.90	-0.65	0.11	0.18	0.18	0.02	0.02
SSA	-3.45	-2.57	-0.59	0.31	-1.96	-1.07	-0.72	0.19	-0.17	-0.12	-0.05	0.00

ANZ means Australia and New Zealand.

ASEAN means Association of Southeast Asian Nations.

EIT means Economies in Transition.

HYAsia means High-Income Asia.

LAM means Latin America.

MENA means Middle East and North Africa.

NAM means North America.

PRC means People's Republic of China.

ROW means Rest of the World.

SAsia means South Asia.

SSA means Sub-Saharan Africa.

WEU means Western European Union except Turkey.

Like South Asia, ASEAN is a smaller net exporter of some of the same products as the PRC, and thereby marginally benefits from the slowdown from a world price effect perspective (Table 13). But, unlike South Asia, ASEAN has stronger links into the PRC market. A slowdown in the PRC translates into slower growth in import demand, and therefore slower export growth from ASEAN to the PRC. This has an adverse effect on the export-price component of ASEAN's terms of trade (Table 13), reflecting the fact that ASEAN's export prices for manufactures are depressed by the slowdown in the PRC (Table 14).

We can now contrast the impact of the PRC's slowdown with that of the slowdown in South Asia. Once again, nonfarm labor productivity growth over the next 20 years is assumed to slow to the rate of High-Income Asia (1.5%/year). This has a less dramatic impact on world prices (Table

12, column 2), since South Asia is a smaller economy, and the slowdown is less dramatic (baseline productivity growth is 3.5%/year instead of 5%/year). The price declines in this case arise for fewer agricultural and food products (crops, ruminants, processed ruminants); petroleum; and forestry, with other prices rising modestly. The total terms of trade impacts of the slowdown in South Asia are positive for all countries in Asia through the world price effect (Table 13). The magnitude of the terms of trade effect on South Asia itself is large and similar to one of the PRC's slowdown scenario (5.54 and 5.06, respectively). The impact on ASEAN is now slightly positive, as ASEAN's links to South Asia are weaker than those to the PRC. Therefore, the positive world price effect dominates the negative export price effect of a South Asia slowdown on ASEAN.

TABLE 14
IMPACT OF ALTERNATIVE SCENARIOS ON ASEAN TERMS OF TRADE BY COMMODITY: CUMULATIVE DEVIATIONS FROM BASELINE FROM 1997 TO 2025 (PERCENT)

COMMODITY	PRC SLOWDOWN			SOUTH ASIA SLOWDOWN			FAST ASEAN TFP CROPS		
	WORLD	EXPORT	IMPORT	WORLD	EXPORT	IMPORT	WORLD	EXPORT	IMPORT
Crops	0.21	-0.01	0.00	0.05	-0.01	-0.01	0.00	-0.13	-0.05
Ruminants	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nonruminants	0.04	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00
Processed Ruminants	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Processed Nonruminants	0.02	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
Processed Food	0.01	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
Textiles and Apparel	-0.04	-0.19	0.03	0.01	0.00	0.00	0.02	0.01	0.00
Manufactures	-0.34	-0.49	0.22	-0.11	-0.11	0.01	0.08	0.04	0.01
Wholesale/Retail Trade	0.31	0.14	0.00	0.08	0.03	0.00	0.03	0.04	0.00
Transport and Communications	-0.07	-0.08	0.02	-0.03	-0.03	-0.01	0.01	0.03	0.00
Financial Services	0.26	0.03	0.00	0.12	0.04	0.00	0.06	0.08	0.00
Housing and Other Services	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Forestry	0.01	-0.03	0.00	0.00	-0.01	0.00	-0.01	0.00	0.00
Fisheries	0.11	0.00	0.00	0.04	0.00	0.01	-0.15	0.01	0.00
Utilities	0.02	-0.03	0.00	0.01	-0.01	0.00	0.00	0.01	0.00
Petroleum	0.09	-0.15	0.01	0.07	0.01	0.04	-0.03	0.00	0.00
Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 15 reports the impact of the PRC and South Asia slowdowns on sectoral production in ASEAN. It is clear that the negative effect of slower growth in these regions is observed in agriculture and food production, forestry, and service sectors. On the other hand, a slowdown in the PRC results in ASEAN textiles and apparel output that is 25.57% higher in 2025 than under the baseline. On the other hand, in the case of South Asia slowdown, ASEAN's output of the manufactures and transport and communication sectors expands.

TABLE 15
IMPACT OF ALTERNATIVE SCENARIOS ON ASEAN PATTERNS OF PRODUCTION BY SECTOR: CUMULATIVE DEVIATIONS FROM BASELINE FROM 1997 TO 2025 (PERCENT)

COMMODITY	SCENARIO		
	PRC SLOWDOWN	SOUTH ASIA SLOWDOWN	FAST ASEAN TFP CROPS
Crops	-0.94	-0.30	45.42
Ruminants	-1.73	0.16	-5.00
Nonruminants	-14.75	-0.72	0.21
Processed Ruminants	0.09	-0.08	-1.35
Processed Nonruminants	-14.88	0.56	-0.84
Processed Food	-0.73	-1.16	7.55
Textiles and Apparel	25.57	-0.21	-1.51
Manufactures	4.91	1.80	0.23
Wholesale/Retail Trade	-10.52	-0.24	-0.65
Transport and Communications	1.50	1.89	-0.85
Financial Services	-3.00	-0.81	-1.74
Housing and Other Services	-1.15	-0.11	2.11
Forestry	-4.15	-1.75	-3.34
Fisheries	-0.02	0.01	-0.06
Utilities	2.90	0.97	-0.79
Petroleum	-1.60	-0.38	-0.20
Construction	-3.62	1.26	1.23

Table 16 reports the change in real income at the poverty line (wage of unskilled labor, deflated by the true cost of living at the poverty line) owing to the slowdown in the PRC and South Asia. Under both scenarios, the incidence of poverty in ASEAN is reduced. The impact of the PRC's slowdown is larger, amounting to a 21 million reduction in the number of people living below poverty line versus 10 million reduction under the South Asia slowdown scenario.

TABLE 16
INCOME AND HEADCOUNT CHANGES AT THE (\$2/DAY) POVERTY LINE IN ASEAN:
CUMULATIVE CHANGES FROM BASELINE IN 2025 DUE TO ALTERNATIVE SCENARIOS

VARIABLE	PRC SLOWDOWN	SOUTH ASIA SLOWDOWN	ASEAN FAST TFP
Total Change in Real Income at Poverty Line	4.22	1.84	6.82
Poverty Elasticity	-2.17	-2.17	-2.17
Percentage Change in Headcount Poverty Ratio	-8.87	-4.16	-13.73
Change in Headcount in Billions (based on number of poor in 2001, millions)	-21.38	-10.03	-32.95

Sources: Authors' estimates. Poverty elasticities from The World Bank.

B. Impact of Faster Crops TFP in ASEAN

The final scenario considered is that of faster productivity growth in ASEAN agriculture, specifically in the crops sector. As seen in Table 3, TFP growth rates in the crops sector in East and Southeast Asia have been negative since 1980, and this pattern is expected to continue for the next 20 years. This poor performance is a direct function of low levels of expenditure on research and development. For example, Anderson, Pardey, and Roseboom (1994) report an agricultural research intensity (research expenditures as a share of agricultural GDP) for the Asia and Pacific region outside of the PRC and India in the early 1980s of 0.32. This is about one sixth the research intensity in developed countries, and only half that in Sub-Saharan Africa! It is no wonder that TFP growth in this region has been languishing.

The final columns in Table 12–15 report the impact on world prices of boosting ASEAN crop productivity growth rates to the rate in the South Asia region over the projection period. Faster TFP growth in crops in ASEAN leads to an increase in crops output and decline in the relative world price of crops (Table 12). Because crop output is an input into other agricultural, food processing, and textiles and apparel, relative world prices of these products experience slightly declines. The total terms of trade impacts for the faster TFP growth in crops in ASEAN are positive for all Asia, but negative for Australia, New Zealand, and the Americas (traditional crops exporters) because of declining world crop prices (Table 13).

It is also important to consider the impact on the pattern of output as well as poverty in the ASEAN region. Table 15 shows that this boost in productivity frees up resources for the remainder of the economy, and permits the economy to grow faster. Only ruminant output slows as this activity must compete with crops for a fixed land base. Higher output translates into higher wages, lower food costs, and higher incomes at the poverty line. Indeed, Table 16 shows that the latter is boosted by nearly 7% in ASEAN. This, in turn, gives rise to a substantial reduction in the poverty headcount, lifting 32.95 million more individuals out of poverty as compared to the baseline.

APPENDICES

APPENDIX A1

DIRECTIONAL DISTANCE FUNCTION MEASURE

Nin et al. (2003) take advantage of information on input allocation by introducing specific input constraints for allocated inputs, modifying the directional distance function measure (Chung, Färe, and Grosskopf 1997). In general, the distance function is defined simultaneously as the contraction of inputs and the expansion of output $(-g_x, g_y)$, which in the case of a single output oriented measure is denoted by $g = (y_j, \mathbf{0})$. The distance function $D(\mathbf{x}, \mathbf{y}; g = (y_j, \mathbf{0}))$, is the optimal objective value for the following problem:

$$\max_{z^k, \beta_i^{k^*}} \beta_i^{k^*}$$

subject to

$$\sum_{k=1}^N z^k y_j^k \geq y_j^{k^*} \quad i \neq j \text{ and } j = 1, 2, \dots, J$$

$$\sum_{k=1}^N z^k y_i^k \geq y_i^{k^*} (1 + \beta_i^{k^*}) \quad h \in A$$

$$\sum_{k=1}^N z^k x_h^k \leq x_h^{k^*} \quad h \notin A$$

$$z^k \geq 0 \quad k = 1, \dots, N$$

where k is the set of countries (k^* is the particular country for which the distance measure is being applied), j is the set of outputs, h is the set of inputs, z^k is the weight on the k th country data, A is the set of allocatable inputs, x_{hj}^k is the level of the allocatable input h used to produce output j of country k , i is the particular output for which efficiency is being measured for country k^* , $i \neq j$ indexes the other outputs (for which efficiency is not being measured), and β is a scalar.

APPENDIX TABLE A2.1
COUNTRIES IN FAO DATA

1. Industrialized Countries
Australia, Austria, Belux, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, United Kingdom, United States
2. Economies in Transition
Albania, Bulgaria, Czech Rep., Slovakia, Hungary, Poland, Romania, former Soviet Union, former Yugoslavia
3. People's Republic of China
4. East and South East Asia
Cambodia, Indonesia, Korea Democratic People's Republic, Republic of Korea, Laos, Malaysia, Mongolia, Myanmar, Philippines, Singapore, Thailand, Viet Nam
5. Developing Asia
Bangladesh, Bhutan, People's Republic of China, Cambodia, India, Indonesia, Iran, Iraq, Jordan, Korea Democratic People's Republic, Republic of Korea Laos, Lebanon, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Syria, Thailand, Turkey, Viet Nam, Yemen
6. Middle East and North Africa
Algeria, Egypt, Iran, Iraq, Jordan, Lebanon, Libya, Morocco, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, Yemen
7. Sub-Saharan Africa
Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Rep, Chad, Congo, Dem R, Congo, Rep, Cote d'Ivoire, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
8. Latin America and Caribbean
Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Suriname, Trinidad and Tobago, Uruguay, Venezuela

APPENDIX TABLE A2.2
AGGREGATION OF GTAP REGIONS

REGION	GTAP REGIONS
Australia and New Zealand (ANZ)	Australia, New Zealand
People's Republic of China (PRC)	PRC
High-Income Asia (HYAsia)	Hong Kong, China; Japan; Korea; Taipei,China
Association of Southeast Asian Nations (ASEAN)	Indonesia, Malaysia, Philippines, Singapore, Thailand, Viet Nam
South Asia (SAsia)	Bangladesh, India, Sri Lanka, rest of South Asia
North America (NAM)	Canada, United States
Latin America (LAM)	Mexico, Central America and Caribbean, Colombia, Peru, Argentina, Brazil, Chile, Uruguay, Venezuela, rest of Andean Pact
Western European Union (WEU) except Turkey	Austria, Belgium, Denmark, Finland, France, Germany, United Kingdom, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, Switzerland, rest of EFTA
Economies in Transition (EIT)	Albania, Bulgaria, Croatia, Czech Republic, Hungary, Malta, Poland, Romania, Slovakia, Slovenia, Estonia, Latvia, Lithuania, Cyprus, Russian Federation and rest of the former Soviet Union
Middle East and North Africa (MENA)	Turkey, the rest of Middle East, Morocco, rest of North Africa
Rest of the World (ROW)	Botswana, the rest of the South African Customs Union, Malawi, Mozambique, Zambia, Zimbabwe, the rest of Southern Africa, Tanzania, Uganda, the rest of Sub-Saharan Africa, rest of the world

APPENDIX TABLE A3
PRODUCTION VALUE WEIGHTS USED TO AGGREGATE TFP GROWTH RATES

REGION	SHARE OF EACH SECTOR BY REGION (2001)			
	CROPS	RUMINANTS	NONRUMINANTS	AGRICULTURE
Industrialized Countries	22.6	41.2	33.6	28.4
Economies in Transition	8.0	12.1	6.8	8.6
PRC	23.0	7.7	38.3	22.5
East and South East Asia	8.9	1.5	5.3	6.8
South Asia	14.8	13.4	2.3	12.3
Middle East and North Africa	4.8	4.5	2.1	4.3
Sub Saharan Africa	6.2	5.0	1.7	5.2
Latin America and Caribbean	11.7	14.5	9.8	11.9
Total	100	100	100	100
REGION	SHARE IN AGRICULTURE (2001)			
	CROPS	RUMINANTS	NONRUMINANTS	TOTAL
World	62	21	18	100
Industrialized Countries	49	30	21	100
Economies in Transition	57	29	14	100
PRC	63	7	30	100
East and South East Asia	82	5	14	100
South Asia	74	23	3	100
Middle East and North Africa	69	22	9	100
Sub Saharan Africa	74	20	6	100
Latin America and Caribbean	60	25	15	100

APPENDIX A4
COMPARISON OF PRODUCTIVITY GROWTH IN AGRICULTURE USING 2001 WEIGHTED SECTOR AVERAGES AND DIRECTIONAL DISTANCE FUNCTION, AGAINST ADJUSTMENT COEFFICIENTS

REGION	ADJUSTMENT COEFFICIENT	PERIOD	WEIGHTED			ESTIMATED		
			TFP	EFF	TCH	TFP	EFF	TCH
World		1961–2000	0.94	-0.22	1.17	0.75	-0.34	1.09
		1961–1970	1.11	-0.26	1.38	0.18	-1.94	2.16
		1971–1980	0.11	-0.83	0.95	0.90	0.38	0.51
		1981–1990	1.06	-0.31	1.42	1.15	0.11	1.04
		1991–2000	1.52	0.57	0.95	0.79	0.12	0.66
Industrialized Countries	0.4624	1961–2000	1.19	0.20	0.99	1.36	0.10	1.26
		1961–1970	1.46	0.70	0.75	1.52	0.36	1.15
		1971–1980	1.51	0.52	0.98	1.88	0.57	1.31
		1981–1990	0.74	-0.47	1.23	0.94	-0.65	1.60
		1991–2000	1.05	0.05	1.00	1.10	0.11	0.99
Economies in Transition	0.3704	1961–2000	0.89	-0.29	1.19	0.81	-0.38	1.19
		1961–1970	1.04	-0.17	1.21	0.87	-0.42	1.29
		1971–1980	-0.21	-0.88	0.69	-0.41	-0.98	0.57
		1981–1990	0.70	-0.29	1.01	1.18	0.54	0.64
		1991–2000	2.09	0.21	1.86	1.59	-0.65	2.25
PRC	0.9847	1961–2000	1.67	-0.47	2.17	1.00	-0.07	1.07
		1961–1970	2.71	-0.20	2.92	2.50	-0.38	2.88
		1971–1980	-1.70	-3.06	1.41	-2.09	-2.73	0.66
		1981–1990	2.71	-0.51	3.39	1.51	0.93	0.57
		1991–2000	3.05	2.01	1.04	2.16	1.96	0.20
East and South East Asia	0.7921	1961–2000	0.18	-0.56	0.75	0.44	-0.55	0.99
		1961–1970	0.48	-0.52	1.01	1.22	-0.38	1.60
		1971–1980	1.07	0.36	0.71	1.29	0.31	0.98
		1981–1990	-0.49	-1.38	0.93	-0.36	-1.60	1.26
		1991–2000	-0.32	-0.68	0.37	-0.38	-0.54	0.16
South Asia	0.695	1961–2000	0.27	-0.21	0.48	0.96	-0.41	1.37
		1961–1970	-0.24	-1.17	0.95	0.99	-0.84	1.85
		1971–1980	-0.55	-0.93	0.39	-0.64	-1.59	0.97
		1981–1990	0.69	0.41	0.29	2.20	-0.30	2.51
		1991–2000	1.19	0.87	0.32	1.31	1.14	0.17
Middle East and North Africa	0.4187	1961–2000	0.03	-0.30	0.34	0.42	-0.69	1.12
		1961–1970	-0.13	-0.57	0.44	0.02	-0.96	1.00
		1971–1980	0.21	-0.18	0.39	1.40	-0.23	1.64

APPENDIX A4. CONTINUED.

		1981–1990	0.26	-0.02	0.28	0.94	-0.27	1.21
		1991–2000	-0.19	-0.43	0.24	-0.67	-1.30	0.64
Sub Saharan Africa	0.6223	1961–2000	0.21	-0.08	0.29	0.57	-0.10	0.67
		1961–1970	-0.24	-0.71	0.47	0.36	-0.44	0.81
		1971–1980	-0.44	-0.67	0.23	-0.12	-0.26	0.14
		1981–1990	0.75	0.49	0.26	0.73	-0.37	1.10
		1991–2000	0.79	0.59	0.20	1.30	0.68	0.61
Latin America and Caribbean	0.7744	1961–2000	0.77	-0.53	1.30	0.71	-0.50	1.21
		1961–1970	0.05	-1.38	1.46	-0.28	-1.96	1.72
		1971–1980	0.70	-0.70	1.41	0.86	-0.68	1.56
		1981–1990	0.67	-0.11	0.78	0.56	-0.35	0.92
		1991–2000	1.66	0.09	1.57	1.70	1.04	0.66

TFP means total factor productivity.

ECH means efficiency change.

TCH means technical change.

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Thomas W. Hertel, Carlos E. Ludena, and Alla Golub project global food supply and demand to the year 2025, with a particular emphasis on Asia. Technological change is found to be the critical factor in determining the likely patterns of trade and structural change. Poverty headcount impacts of baseline and alternative technological change scenarios are also explored.

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