A multi-regional representation of China's agricultural sectors using SinoTERM

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This paper outlines a version of SinoTERM, a multi-regional computable general equilibrium model of China that has been updated and disaggregated further to enhance the agricultural detail. A version of the model is publicly available and will be useful to computable general equilibrium (CGE) modelers studying Chinese agricultural issues (see http://www.monash.edu.au/policy/sinoterm.htm). The paper outlines data sources for building SinoTERM. It contains a CGE application to agriculture in China. Unlike the national input-output table published by the National Bureau of Statistics, the master database of SinoTERM contains many agricultural sectors. CGE models that represent a nation as a single economy may offer rich insights into winners and losers from particular policy scenarios. Multi-regional analysis takes this a step further by comparing outcomes for regions in which particular industries are a relatively large part of the economy.

This paper builds on the first SinoTERM paper (Horridge and Wittwer, 2008) in several ways. First, the database is disaggregated further to represent tea, sugar cane and silkworms as individual sectors in the CGE database. Second, given the extraordinary economic growth in China, the national and regional database has been updated to 2006 using data from the 2007 yearbook. Third, the paper contains an application to agriculture: it examines the impacts of productivity growth in different agricultural sectors in China.

Keywords: Agricultural R&D, Regional modeling, CGE modeling.
JEL categories: Q160, R130, C680.

1. Introduction

China's spectacular growth since the early 1980s has been a dominant event in the global economy. China's demand for resources has been largely responsible for an increase in world commodity prices in the new millennium. Years of rapid economic growth have transformed relatively wealthy cities on the eastern seaboard of China. At the same time, rural sectors and inland provinces have experienced modest growth. Moreover, rapid economic growth is bringing with it significant environmental issues, including greenhouse gas emissions, air quality, land degradation, loss of farming land to urban development and water quality and availability. Growing concerns regarding unequal growth and environmental issues are likely to raise demand for a model that treats China as more than one economy. Such a model is SinoTERM, a multi-regional computable general equilibrium (CGE) model that includes sectoral detail for all the provinces and municipalities of China (Horridge and Wittwer, 2008).

During this era of rapid growth, it would appear that China's agricultural sector has been neglected in policy direction relative to other sectors. Even the input-output table published by the National Bureau of Statistics (NBS) (2007) is symptomatic of what appears to have been until now a lack of interest in agriculture. The input-output table for 2002 (the most recent publication) contains 122 sectors, including just three for agriculture. Yet agriculture employs 300 million of China's 700 million workforce. A priority in developing a useful multi-regional database for SinoTERM was to increase the number of agricultural sectors. Horridge and Wittwer (2008) increased the number of sectors in the national input-output database from 122 to 137 by splitting agriculture and food into more sectors.[1]

Now, another priority has emerged in modeling the regions of China. China's real GDP grew by 48 percent from 2002 to 2006 (NBS 2007, chapter 3). This was fuelled by extraordinary growth in manufactures exports and accompanied by massive increases in imports of raw materials. This provides a significant motivation to update the published national input-output table. We outline the data sources and methodology used to modify the national input-output table so as to update the database to 2006. In addition, we created new sectors in agriculture, namely tea, sugar cane and silkworms, thereby expanding to 140 sectors and dovetailing the agricultural data produced by the NBS to the input-output table.

2. Previous multi-regional representations

Regional modelers of the Chinese economy in the past have relied on multi-regional input-output tables. Typically, these are based on a handful of individual provincial input-output tables. In joining provincial tables together, there are difficulties in matching sectors and years. It is unlikely that a multi-regional table devised by this method is up-to-date. Horridge *et al.* (2005) introduced a new methodology for devising a multi-regional input-output database. The key to this methodology is to start with as many national sectors as possible, and to split it based on regional shares of national activity. When it comes to estimating regional shares of national activity, sectoral disaggregation simplifies the task rather than making it more

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[1] Unfortunately, the National Bureau of Statistics is planning to represent more secondary and services sectors in the 2007 input-output table without more agricultural detail (see http://www.oecd.org/dataoecd/55/11/39178799.pdf).

complex. For example, it is a relatively easy task to obtain provincial shares of national output for wheat, corn, rice, sugar cane, tea or grapes and various other crops (see NBS 2007, table 13-17); it is a more complex task to obtain such shares for a composite crops sector. Similarly, estimates of broad mining activity by region may be difficult to obtain, whereas estimates of iron ore, non-ferrous ores, coal, oil and gas potentially are easier to obtain.

Previous estimates of a multi-regional input-output database for China include Okuda *et al*. (2004), comprising 38 sectors and 30 regions for 1997. Modelers have undertaken a number of studies with relatively small multi-regional input-output models of China in the past, covering an array of economic issues. For example, Guan and Hubacek (2006) devised such model that included water accounts. Ueta *et al*. (2006) used a multi-regional input-output framework to analyse greenhouse gas emissions.

Horridge and Wittwer (2008) presented an application based on the 137 sector, 31 region SinoTERM database. Reflecting sectors and regions specific to the simulation (a rail construction project), the master database was aggregated to fewer sectors and a handful of regions so as to speed solution and simplify the representation of results. The present paper uses the same framework, with an updated database, to concentrate on an agricultural scenario.

3. Updating the national database and creating SinoTERM

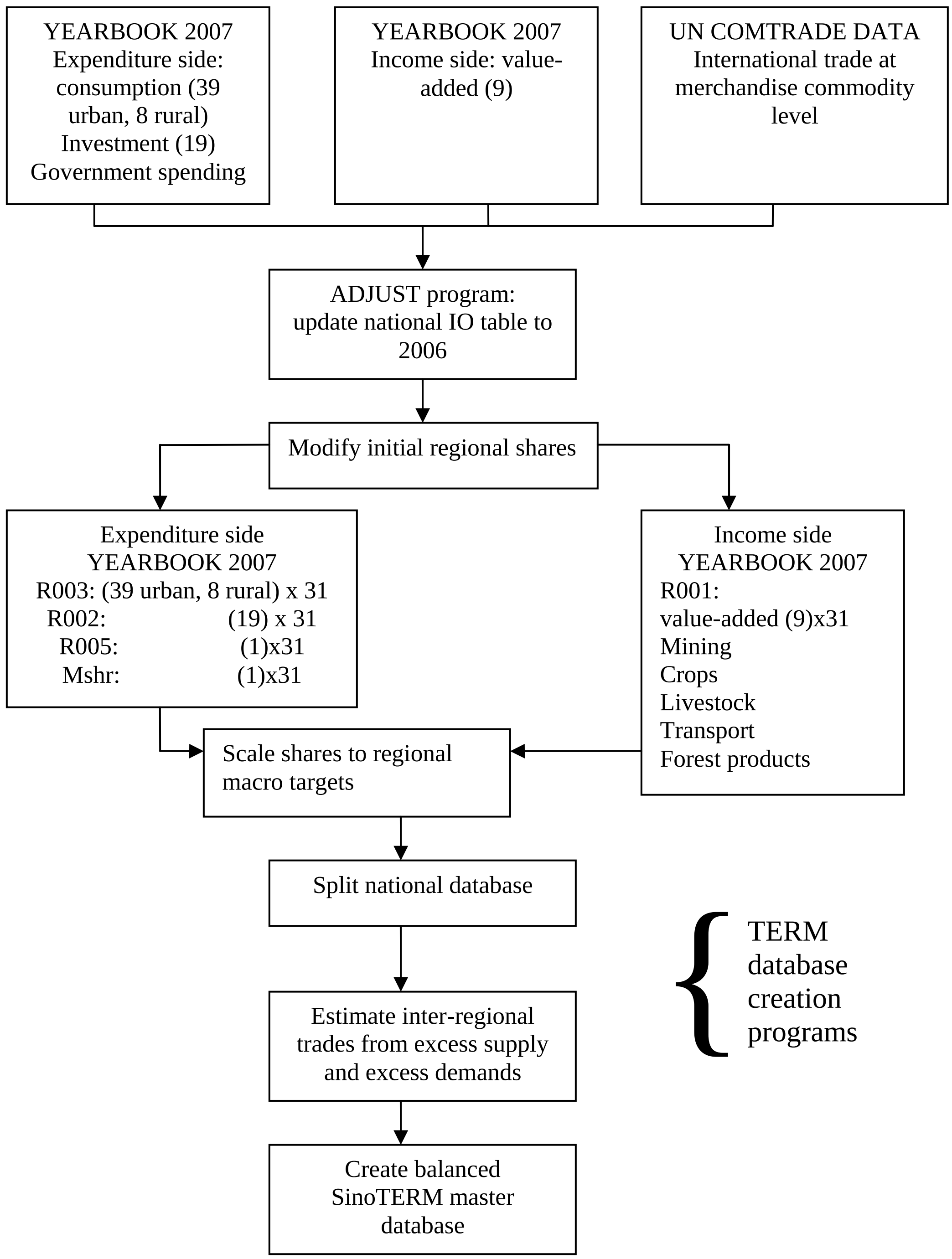
The NBS yearbook (2007) is the cornerstone of our updated multi-regional database, both in the regional and sectoral dimensions. On the expenditure side, the NBS provides household consumption for 8 broad rural sectors and 39 broad urban household sectors. Similarly, aggregate investment is reported for 19 broad sectors. These data are available by province, thereby providing regional shares in addition to broad sectoral targets. The yearbook also contains aggregate government spending, and aggregate international exports and imports by province. On the income side, NBS reports value-added for 9 broad sectors in each province.

So far, it appears that the yearbook does not contain sector-specific that we could use to update individual sectors within the national input-output database. The yearbook includes some commodity data on international trade but we chose to use more disaggregated trade from the UN’s Comtrade database (http://comtrade.un.org/db/). These are particularly useful in updating sectors with the most rapid trade growth: for exports, these include manufactures while imports have been dominated by rapidly growing imports of metal ores, coal, oil and gas. The latter are particularly important as values of such imports have risen dramatically since 2002 with escalating world prices.

The ADJUST program used to update the national database

The development of the multi-sectoral dynamic MONASH CGE model provided a useful tool for updating a database (Dixon and Rimmer, 2002). This approach updates database values by a combination of changes in prices and quantities, based on economic theory and available observations.

Figure 1: Programs for updating the national database and creating the regional database



Notes: R00* refers to regional shares – R001= production, R002=investment, R003=household spending, R004=exports, R005=government spending, Mshr= imports.

We developed a levels version of a database updating program (ADJUST) for the ORANI suite of models that allows the practitioner to target values directly.[2] Unlike a dynamic CGE approach to updating, this approach contains no economic theory.

For example, the practitioner may be aware of import tariff reductions or rapid technological growth in particular sectors that have occurred in a particular time period. In a dynamic CGE model, such changes can be imposed on the model to update it in the form of tariff or technological shocks. This allows the modeler to target specific sectors, for example, in which import tariffs have been cut. With the levels-based ADJUST program, the value of tariff revenue rather than a change in the tariff rate would be the exogenous target.

Both the dynamic CGE approach and the levels database adjustment approach have roles to play in updating the database of a CGE model. The dynamic approach has advantages in dealing with specific sectors (particularly dealing with known changes in taxes and outputs) while the levels approach is useful in hitting value targets. Although we did not use a dynamic update in this exercise, we could do so with appropriate input data.

Figure 1 outlines the procedure for updating the national database and creating SinoTERM. Prior to the steps shown in figure 1, a suite of programs split the national table to improve the representation of agriculture, thereby increasing the number of sectors from 122 to 140. An important part of the updating and regional database creation procedures is to program as much as possible of the inputs. In addition to making revisions to databases more rapid than with alternative methods, programs also contain a record of the methods used and the assumptions made in the database procedures. If improved data come to light, or indeed when the National Statistical Bureau releases a new input-output table, the programming approach will allow us to make adjustments to the regional database with relative ease.

4. An application of SinoTERM to agricultural productivity

We have outlined a methodology for splitting the three agricultural sectors in the published 2002 national input-output database into many. We updated the national database to 2006 and then split it into regions. The database within SinoTERM is now ready for detailed regional analysis in China. Our application concerns agriculture, using an aggregation of the master database to 49 sectors for all 31 regions.

For our illustrative simulation, we turn to agricultural productivity, based on a premise that agriculture has received little attention from policy makers in China during the manufacturing export boom. In a review of productivity growth in Chinese agriculture, Carter *et al*. (2003) note that while rapid productivity growth occurred in the period 1979-1987, a slowing of productivity growth was evident in the period 1988-1996. Fan *et al*. (2002) observe that in 1997, government investment in rural areas represented a share of total investment that was disproportionally small relative to the rural share of China’s population. Moreover, the share of this investment spent on agricultural research was only 2.2 percent. This finding is consistent with other studies in pointing to a relative neglect of agriculture. For example, Yang (2002)

[2] See http://www.monash.edu.au/policy/archivep.htm item TPMH0085.

concludes that there is a bias in fiscal and credit policies towards urban activities. Other studies documenting policy bias towards urban growth include Zhang and Kanbur (2005).

Given that there appears to have been a bias against investment in agricultural research in China since the late 1980s, it is highly probable that there will be a high rate of return from investments to redress the bias. Moreover, environmental issues including climate change, land degradation and, particularly in irrigation regions of western China, rising salinity, will increase the need for agricultural research to maintain or increase productivity. Studies of R & D in agriculture in other countries have found high rates of return from public investment. Mullen (2007) discusses the Australian case. Ball (2005) summarizes findings from United States Department of Agriculture data that productivity growth was responsible for all output growth in agriculture in the USA over the past six decades. It is possible that a slowing of productivity growth in US agriculture in the 1990s was due to lack of growth in public investments in research.

The objective of the present study is to demonstrate how a particular set of productivity outcomes will impact on the Chinese economy at the regional and sectoral levels. Future studies using SinoTERM may be able to make use of actual estimates from econometric analysis, or simulate the expected impacts of specific agricultural research.

The assumed productivity shocks

The benefits of some agricultural research are crop-specific, while other research has generic benefits. Without knowing the benefits of a particular research program, we confine our simulation to an illustrative application. An issue arising from returns to research is also how region-specific the benefits are. We are examining the long-run benefits. We assume that benefits do not remain specific to particular locations. Our scenario examines the sectoral and regional impacts of a 10 percent improvement in primary factor productivity in all agricultural sectors in each region.

In practice, productivity gains may not necessarily spread to producers of a particular crop or livestock in regions. Some R&D may concentrate on, for example, improved irrigation practices in the deserts of Xinjiang. This may not apply to producers of the same crop in a different environment. It might be that despite the efforts of policy makers to spread R&D over all crops and livestock in China, particular sectors do not benefit from the same growth as others. In any R&D activity, there is a risk of misdirection in research endeavor or research into an output for which demand is shrinking relative to other outputs. But it is not our purpose to surmise in which sectors productivity growth will provide the largest direct economic benefit to China. Rather, we are interested in how a general pattern of agricultural productivity gains will affect the regional economies of China.

Model closure

The choice of model closure (that is, the set of variables that are endogenous and the set that are exogenous) has a substantial influence on modeled outcomes. We are using a comparative static model. If we are going to model hypothetical returns from research, it is appropriate to do so in a long-run setting. That is, investment in research proceeds over several years, with initial benefits from the research, arising through productivity gains, only starting towards the end of the particular research program. In a long-run setting, we are depicting the impact of benefits perhaps a decade after the research was undertaken.

In the long run, we assume that there is a substantial scope for supply-side adjustment in the economy. That is, there is sufficient time for capital stocks to adjust (via investments becoming operational capital over time) so as to eliminate short-run variations in rates-of-return on capital. In the labor market, we assume that there is imperfect mobility of labor between regions. That is, if the labor market in a particular region (one of the 31 provinces and municipalities) strengthens relative to other regions, there will be inward migration of workers to that region combined with an increase in real wages relative to other regions.

Since we allow capital stocks to adjust, we need to ensure that we fund capital creation. In this comparative static setting, we make the investment-to-capital ratios in each sector exogenous. This is sufficient investment to maintain long-run capital stocks, but it does not fully cost the creation of additional capital in the interval prior to our long-run snapshot of the economy. One way to do this is to run a balance of payments surplus equal to the annualized payment on capital creation costs that are in addition to those of the base case. Additional capital contributes 0.23 percent to GDP in the simulation. We could treat this as the annualized payment to capital owners by running a balance-of-trade surplus amounting to 0.23 percent of GDP. This will ensure that we do not overstate the amount of additional income available for domestic consumption.

A consumption function ties percentage changes in nominal consumption to percentage changes in real GDP. This is preferable to tying real consumption and real GDP, which would not allow terms-of-trade changes to alter the real consumption to real GDP ratio. We could tie real government consumption to real household consumption or, as we choose to do, leave real government consumption exogenous. We also leave the national balance-of-trade as a share of GDP exogenous (and shocked to pay for additional capital), so that on the expenditure side of the model, real consumption is the main indicator of welfare. However, in our simulation, we have 31 regions, each with a rural and urban household, so that there are 62 households in total. In any simulation, we are likely to have groups of households that gain substantially more than others. We need to explain such differences when we analyze results.

Analysing the macroeconomic results

Although our simulation concerns shocks to agricultural sectors only, we start the analysis by first explaining macroeconomics results using back-of-the-envelope (BOTE) calculations. To explain this, we define GDP (Y) as a function of underlying technology A, capital K and labor L (fixed nationally in the long run):

$$Y = \frac{1}{A} F(K, \overline{L}) \qquad (1)$$

From this, we derive an economy-wide expression for the marginal product of capital:

$$(\frac{\overline{r}}{p}) = \frac{1}{A} F_k(K, \overline{L}) \qquad (2)$$

Given that the rate-of-return on capital is fixed in the long run, (2) is approximately constant.[3] This means that on the RHS, if there is technological improvement (i.e., a fall in A), then capital stocks K must rise so as to restore the pre-simulation rate-of-return since aggregate employment L is fixed. We can calculate the direct contribution of technology to real GDP by multiplying the direct shock by agriculture's share of national GDP: agriculture's share is 6.7 percent in the initial database, so the BOTE contribution to real GDP is 0.67 percent [=0.1 x 0.067]. In the model solution, national capital stocks grow as predicted by our interpretation of equation (2) by 0.66 percent. As returns to capital account for 35 percent of GDP, the contribution of capital stocks growth to GDP is 0.23 percent [=0.35x0.66]. The BOTE calculation indicates a real GDP increase of 0.90 percent, equal to the modeled outcome (0.903 percent, table 1). The BOTE result may in practice differ from the modeled outcome due to indirect tax revenues and changes between pre-simulation and post-simulation factor shares in the database.

Next, we consider regional macroeconomic impacts. The provinces in which agriculture has the largest share of regional GDP, as shown in table 2, are Hainan (18.2 percent), Tibet (17.6 percent), Guangxi (13.9 percent) and Sichuan (12.8 percent). Agriculture's share is smallest in the municipalities of Shanghai (0.6 percent), Beijing (1.0 percent) and Tianjin (1.7 percent), and, among the provinces, Shanxi (1.5 percent). We expect the regions with the largest real GDP growth to be those where agriculture's share of GDP is largest, as is evident in the real GDP outcomes (Hainan 2.13 percent, Guangxi 1.95 percent, Tibet 1.79 percent and Sichuan 1.59 percent, Table 1).

We assume that national employment is fixed in the long run, with all labor market adjustment occurring by changes in real wages, which rise in this scenario by a national average of 1.48 percent. In regions in which the productivity gains result in a strengthening of the labor market that is less than the national average, regional employment falls relative to the base case (through inter-regional migration) and real wages rise less than the national average. In all regions, real wages rise relative to the base case.

Rural households benefit from a larger percentage gain in aggregate consumption than urban households. This is because available data on rural households indicate that food accounts for a larger proportion of household expenditure than for urban households. This is consistent with Engel's law: rural households have lower average incomes than their urban counterparts. Productivity improvements lower the price of agricultural inputs to food production, thereby having a larger effect on the budgets of rural households than urban households.

Puzzles arise when we look at the ranking of household consumption gains by region. Rural households in Tibet have a smaller proportional gain in real consumption than rural households in any other region. In a relatively agriculture-intensive economy, productivity improvements

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[3] In percentage change terms, the rate-of-return on capital is the price of capital minus the price of constructing capital. The price term in the rate-of-return expression is more activity-specific than the GDP deflator used in the marginal product of capital expression

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in agriculture will down drive down the terms-of-trade (i.e., the price a region receives for international and inter-regional exports relative to international and inter-regional imports). Candidates for larger terms-of-trade losses in this scenario will be those regions with agriculture as a relatively large share of GDP, whose own usage of agricultural outputs is relatively small.

Table 1: Macroeconomic outcomes by region
(% change relative to base case)

	Real GDP	Rural H'hold consumption	Urban H'hold consumption	Real Investment	Real Govt spending	Export Volumes (international)	Import Volumes (international)	Aggregate Employment	Ave Real Wage	Aggregate Capital Stock	GDP price index	Export price index
Beijing	0.236	1.848	0.553	0.218	0.000	0.572	-0.067	-0.015	1.461	0.313	-0.124	-0.143
Tianjin	0.358	2.041	0.622	0.224	0.000	0.814	0.041	0.043	1.519	0.354	-0.236	-0.203
Hebei	1.150	0.904	-0.081	1.105	0.000	2.157	0.763	-0.196	1.278	0.768	-1.350	-0.533
Shanxi	0.361	1.611	0.495	0.280	0.000	0.641	0.124	0.091	1.568	0.372	-0.245	-0.160
InnrMongolia	0.858	1.137	-0.058	0.820	0.000	1.736	0.544	-0.189	1.285	0.615	-1.100	-0.430
Liaoning	0.963	1.668	0.717	0.873	0.000	1.688	0.652	0.126	1.604	0.754	-0.823	-0.418
Jilin	1.366	1.081	0.055	1.412	0.000	2.855	1.029	-0.170	1.304	0.886	-1.586	-0.703
Heilongjiang	0.932	1.370	0.452	0.840	0.000	1.566	0.456	0.012	1.488	0.703	-0.956	-0.388
Shanghai	0.239	2.266	0.646	0.130	0.000	0.597	-0.061	0.041	1.518	0.301	-0.102	-0.149
Jiangsu	0.640	1.639	0.385	0.515	0.000	1.107	0.330	0.043	1.519	0.498	-0.533	-0.275
Zhejiang	0.414	1.396	0.141	0.302	0.000	0.986	0.115	-0.096	1.379	0.347	-0.383	-0.245
Anhui	1.354	1.297	0.256	1.294	0.000	2.308	0.869	-0.012	1.464	0.922	-1.446	-0.570
Fujian	0.926	1.830	0.701	0.696	0.000	1.424	0.438	0.190	1.668	0.698	-0.715	-0.353
Jiangxi	1.362	1.642	0.454	1.246	0.000	2.095	0.863	0.132	1.610	0.971	-1.312	-0.518
Shandong	0.747	1.265	0.141	0.708	0.000	1.414	0.474	-0.086	1.389	0.557	-0.777	-0.351
Henan	1.380	0.893	-0.178	1.305	0.000	2.550	0.837	-0.193	1.281	0.894	-1.641	-0.629
Hubei	1.190	1.524	0.250	1.129	0.000	2.138	0.667	0.013	1.490	0.839	-1.262	-0.528
Hunan	1.373	1.395	0.085	1.320	0.000	2.551	0.725	-0.039	1.437	0.922	-1.574	-0.629
Guangdong	0.749	2.301	0.828	0.572	0.000	1.162	0.314	0.210	1.689	0.636	-0.477	-0.289
Guangxi	1.948	1.550	0.660	1.978	0.000	2.695	1.299	0.180	1.658	1.349	-1.988	-0.664
Hainan	2.130	1.348	0.345	1.903	0.000	3.506	1.217	-0.001	1.475	1.096	-2.400	-0.860
Chongqing	1.328	1.927	0.230	1.238	0.000	2.830	0.773	-0.013	1.463	0.937	-1.424	-0.697
Sichuan	1.589	1.430	0.071	1.517	0.000	2.805	0.916	-0.028	1.448	1.079	-1.802	-0.691
Guizhou	1.276	1.760	0.342	1.215	0.000	2.519	0.566	0.119	1.597	0.949	-1.312	-0.621
Yunnan	1.385	1.543	0.224	1.277	0.000	2.419	0.638	0.060	1.537	0.982	-1.504	-0.597
Tibet	1.787	0.374	-0.288	1.274	0.000	5.316	0.545	-0.318	1.154	0.912	-2.835	-1.292
Shaanxi	0.672	1.343	0.164	0.575	0.000	1.279	0.296	-0.062	1.414	0.528	-0.711	-0.317
Gansu	1.250	1.079	-0.391	1.373	0.000	2.525	0.759	-0.251	1.222	0.775	-1.659	-0.623
Qinghai	0.941	1.609	0.400	0.858	0.000	1.517	0.522	0.077	1.554	0.762	-0.976	-0.376
Ningxia	0.911	1.558	0.316	0.829	0.000	1.748	0.487	0.013	1.489	0.718	-0.920	-0.433
Xinjiang	1.372	1.026	-0.006	1.343	0.000	1.717	0.824	-0.163	1.311	0.958	-1.713	-0.425
National	0.903	1.469	0.363	0.812	0.000	1.205	0.493	0.000	1.476	0.663	-0.902	-0.299

Table 2: Broad sectoral contributions to regional value-added, 2006 database (%)

	Agriculture	Forestry, fishing and mining	Food	Textiles, clothing & footwear	Other manufacturing	Services	Total
Beijing	1.0	0.2	0.6	1.1	22.4	74.7	100.0
Tianjin	1.7	0.8	3.6	5.5	39.0	49.3	100.0
Hebei	10.1	2.6	4.6	7.1	32.4	43.2	100.0
Shanxi	1.5	6.4	3.5	7.7	37.0	44.0	100.0
InnrMongolia	7.7	8.5	3.4	6.4	27.0	47.1	100.0
Liaoning	6.0	4.5	3.6	5.2	31.6	49.2	100.0
Jilin	11.7	4.1	2.5	5.0	28.7	47.9	100.0
Heilongjiang	6.5	5.8	3.5	7.4	29.7	47.0	100.0
Shanghai	0.6	0.2	1.5	3.2	42.3	52.2	100.0
Jiangsu	4.2	1.5	3.4	6.7	37.8	46.4	100.0
Zhejiang	3.3	1.5	5.0	8.9	32.9	48.3	100.0
Anhui	10.7	5.3	3.9	7.9	26.3	45.9	100.0
Fujian	5.4	4.8	3.8	6.5	34.9	44.6	100.0
Jiangxi	9.6	5.1	3.5	7.5	29.8	44.5	100.0
Shandong	6.0	2.5	4.9	8.2	31.0	47.4	100.0
Henan	12.3	2.0	5.2	10.5	30.5	39.5	100.0
Hubei	9.1	4.0	3.4	7.2	30.1	46.1	100.0
Hunan	11.3	3.9	3.7	8.0	25.1	48.0	100.0
Guangdong	3.4	1.5	3.6	6.9	36.7	48.0	100.0
Guangxi	13.9	4.9	5.2	6.8	23.0	46.4	100.0
Hainan	18.2	12.0	3.7	4.9	13.8	47.3	100.0
Chongqing	10.2	1.5	3.2	7.1	28.3	49.9	100.0
Sichuan	12.8	3.7	4.1	8.7	25.0	45.8	100.0
Guizhou	9.2	8.6	4.0	9.1	24.7	44.5	100.0
Yunnan	10.5	6.3	4.3	7.8	23.5	47.6	100.0
Tibet	17.6	2.0	2.2	1.7	5.2	71.5	100.0
Shaanxi	5.2	6.9	5.0	11.2	30.1	41.6	100.0
Gansu	11.5	4.8	2.7	5.5	18.3	57.3	100.0
Qinghai	6.3	6.6	3.8	8.6	28.4	46.4	100.0
Ningxia	6.3	6.6	3.8	7.1	20.1	56.0	100.0
Xinjiang	11.3	8.2	6.2	4.9	22.7	46.8	100.0
National	6.7	3.1	3.8	7.1	31.6	47.7	100.0

To gain some insight into why Tibet does not do as well as other regions, we again look at table 2. In Tibet, food processing accounts for 2.2 percent of regional value-added activity. This share is ahead only of the Beijing and Shanghai municipalities. This most likely reveals a quirk of the database: Tibet’s geography and transport links (at least before the construction of the rail link to Lhasa) imply little external trade, indicating that most of the region’s agricultural output is used within the region. The database indicates that livestock accounts for a large share of Tibet’s agriculture. It is likely that virtually all livestock products (meat and wool) are consumed within the region, yet the existing TERM database indicates substantial sales to other regions. To the extent that the database overstates sales of Tibetan agricultural products to other regions, it also overstates the adverse terms-of-trade impact of the simulation on the region. This is an example of a database issue that was revealed to us by a simulation. With further model development, we could redress this apparent deficiency.

Table 3: Sectoral outcomes by region
(% change relative to base case)

	Grains	Tea	VegOthCrop	FruitGrapes	Livestock	Meat	EggsMilk	OthPrimary	OthFoodDrink	TCFs	OthManufact	Utilites	Construction	Transport	OthServices
Beijing	1.7	0.0	2.4	1.7	1.9	2.8	3.6	-0.3	0.0	0.2	-0.1	0.3	0.5	0.4	0.3
Tianjin	1.9	0.0	3.5	1.9	2.6	3.5	4.8	0.0	0.6	0.6	0.1	0.5	0.4	0.5	0.4
Hebei	3.6	0.0	3.8	3.4	3.3	4.6	5.6	0.7	1.1	1.4	1.3	0.7	1.0	0.8	0.4
Shanxi	2.2	0.0	2.0	1.9	2.3	2.5	2.6	0.1	0.5	0.5	0.2	0.4	0.4	0.6	0.4
InnrMongolia	3.2	0.0	3.0	2.7	2.7	4.4	3.5	0.6	0.8	1.1	1.0	0.6	0.8	0.7	0.4
Liaoning	3.3	0.0	3.8	2.9	3.2	4.4	5.9	0.5	1.0	1.3	0.9	0.7	0.9	0.9	0.7
Jilin	3.6	0.0	4.1	3.5	3.5	4.7	5.1	0.8	1.2	1.6	1.7	0.8	1.2	0.9	0.6
Heilongjiang	3.2	0.0	3.5	2.7	3.1	4.0	4.7	0.4	1.0	1.2	1.0	0.7	0.9	0.8	0.5
Shanghai	2.6	0.0	3.2	2.0	1.7	2.2	2.6	-0.5	0.5	0.5	-0.1	0.3	0.3	0.4	0.4
Jiangsu	4.4	6.4	4.9	3.1	2.9	3.2	6.0	0.1	0.9	1.1	0.5	0.5	0.5	0.6	0.4
Zhejiang	3.4	16.3	4.3	2.5	2.2	2.3	4.1	-0.2	0.7	0.7	0.1	0.4	0.3	0.4	0.3
Anhui	3.8	9.3	4.0	3.5	3.7	4.1	6.2	0.9	1.3	1.7	1.5	0.9	1.1	1.0	0.7
Fujian	3.7	16.2	5.2	3.0	3.6	2.8	5.0	0.3	1.0	1.3	0.7	0.7	0.7	0.9	0.7
Jiangxi	4.0	8.7	4.5	3.6	3.7	3.0	5.0	0.9	1.3	1.7	1.4	1.0	1.0	1.1	0.8
Shandong	3.3	0.0	3.6	3.4	3.0	4.5	5.4	0.3	0.9	1.1	0.7	0.6	0.7	0.6	0.3
Henan	3.5	6.2	4.0	3.6	3.6	4.2	5.2	0.9	1.2	1.7	1.6	0.9	1.2	1.0	0.5
Hubei	3.6	8.8	4.0	3.4	3.4	2.8	6.0	0.9	1.1	1.5	1.3	0.9	1.0	0.9	0.6
Hunan	4.0	10.0	4.4	3.8	3.8	3.2	6.4	1.0	1.4	1.8	1.6	0.9	1.1	1.0	0.6
Guangdong	4.3	11.3	5.0	2.7	3.1	2.6	4.4	0.2	1.3	1.1	0.5	0.7	0.6	0.8	0.6
Guangxi	4.0	8.6	4.3	4.3	4.4	3.3	5.7	1.5	2.4	2.6	2.3	1.3	1.6	1.3	1.0
Hainan	4.6	0.0	5.8	4.4	4.6	4.1	8.2	1.7	2.3	2.6	2.4	1.2	1.3	1.1	1.1
Chongqing	3.6	7.1	3.9	3.6	3.4	3.1	5.4	0.9	1.2	1.7	1.6	1.0	1.1	1.0	0.7
Sichuan	3.9	9.2	4.3	3.9	3.9	3.6	5.0	1.2	1.5	2.1	2.0	1.1	1.2	1.1	0.7
Guizhou	3.4	7.1	3.6	3.5	3.8	2.8	5.0	1.0	1.3	1.6	1.5	1.0	1.1	1.1	0.8
Yunnan	3.5	9.8	3.8	3.5	3.7	3.6	3.5	1.1	1.5	1.8	1.7	1.1	1.0	1.0	0.7
Tibet	5.1	0.0	5.6	5.1	4.2	8.2	6.0	2.1	2.5	2.9	2.9	1.4	1.1	1.3	1.0
Shaanxi	2.4	0.0	2.8	2.7	2.6	2.9	3.2	0.4	0.7	0.9	0.6	0.6	0.6	0.7	0.4
Gansu	3.7	0.0	4.1	3.9	3.5	4.6	3.8	0.9	1.4	1.8	1.8	0.9	1.1	0.9	0.5
Qinghai	2.9	0.0	2.9	2.8	2.9	4.8	3.1	0.5	0.9	1.3	1.0	0.8	0.8	0.9	0.6
Ningxia	3.0	0.0	3.9	2.9	2.8	5.4	4.4	0.6	0.8	1.2	1.0	0.8	0.8	0.9	0.6
Xinjiang	3.8	0.0	3.4	3.7	3.3	8.0	6.3	0.8	1.8	1.9	1.8	1.0	1.1	1.0	0.6
National	3.8	11.5	4.2	3.3	3.4	3.9	4.9	0.6	1.1	1.3	0.8	0.7	0.8	0.8	0.5

Sectoral results

At the sectoral level, the largest proportional increases occur in the directly affected agricultural sectors. In the case of tea, the percentage increase in output exceeds productivity growth (Table 3, bottom row). This occurs because a relatively high proportion of tea in the database is exported (25 percent). Export demands are more elastic than other sales. In the long run, factors used in tea production increase relative to the base case: in other agricultural sectors, factor usage shrinks as output increases by less than 10 percent. We can calculate the percentage change in composite factor inputs (land, labor and capital) by adding the percentage changes in output and input requirements. For example, Jiangsu's tea output increases by 7 percent, indicating a decrease in the region's primary factor usage in tea production of 3 percent.

Downstream food sectors increase output in response to cheaper agricultural inputs. Whereas all agricultural sectors except tea reduce primary factor usage in response to the productivity gains, additional labor and capital are required in non-agricultural sectors to increase output. Since aggregate consumption rises for both rural and urban households in all regions, demands for non-agricultural commodities rise, assuming positive expenditure elasticities; there is an increase in output of all non-agricultural sectors at the national level. The workforce based in agriculture falls by 6.7 percent as a consequence of the productivity improvement. This is equivalent to a movement of 20 million workers out of agriculture. If there had been no increase in agricultural output, a 10 percent productivity gain would have led to an exodus from agriculture of one tenth of the agricultural workforce or 30 million workers.

Terms-of-trade losses and productivity gains

Notwithstanding any database concerns we may have, should adverse terms-of-trade shocks in any way discourage investment in agricultural R&D? The global experience is that the terms-of-trade have moved against agriculture over a number of decades.[4] Productivity growth has offset terms-of-trade losses, and indeed the consequent outward supply shifts in agriculture have been largely responsible for such losses. The difficulty for farmers has been that some commodities have suffered larger terms-of-trade declines than others (FAO, 2004). What is clear is that farmers who are most vulnerable to income losses are those whose productivity is growing relatively slowly. Trade distortions in agriculture have contributed to terms-of-trade declines. The European Union through its Common Agricultural Policy is usually regarded as the main offender. The United States' Export Enhancement Program has also contributed to global distortions, as have the protective policies of other developed countries, notably Japan. Reforms in agriculture are regarded as essential to a successful completion to the Doha round of WTO negotiations, but are proving difficult to realize (Martin and Anderson, 2008).

It is likely that WTO-led liberalization of agriculture will increase the returns from R&D in agriculture, although these will be largest for nations that export a large share of agricultural production. Domestic food policies in China have been gradually liberalized since the early 1990s. The main issues in Chinese agriculture since then appear to have concerned supply-side constraints including lack of R&D and poor rural infrastructure.

Given that some regions lose their share of national employment as productivity grows, will such gains reinforce disparities in growth between the booming seaboard and inland regions of China? Since agriculture appears to have been neglected relative to other sectors, it appears

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[4] Water, fuel and land constraints have contributed to a quite recent price revival for some agricultural commodities.

that the converse is true: slowing of productivity growth in agriculture may have widened disparities in growth. It is highly probable that the contribution of agriculture to GDP in China will shrink from its 2006 share (6.7 percent) in the future, as has been the case in developed economies. Productivity gains in agriculture will move workers off the land into the manufacturing and services sectors. This may result in growth in regional cities and towns, and shrinkage in smaller settlements. Productivity growth in agriculture will raise farm incomes even as agriculture's share of GDP falls. Raising the education of rural workers will increase the opportunities that they have outside of farming. For those who remain on the land, raised education levels will improve the transmission of new knowledge. As elsewhere, rural China has to face the challenges of climate change, land degradation, water quality and plant and animal disease management.

5. Future directions and conclusion

Our split into rural and urban households for each province indicates that in proportional terms, rural households gain more from agricultural productivity growth than urban households. This result is mainly a consequence of relatively poor rural households spending a larger proportion of their incomes on food products, the prices of which fall with productivity growth in agriculture. This reflects demand characteristics rather than differences in factor composition on the supply side of the model.

SinoTERM contains sectoral and regional disaggregation, yet at present it contains no disaggregation of the labor market into skill types. Such a disaggregation may enrich modeling scenarios that concern urban-rural migration, of which the scenario we examine is an example. There may also be some insights from attempting to link household spending to ownership of factors. Our experience is that specific policy problems provide the motivation and resources for model developments. The issue of rural-urban migration is but one of many in which SinoTERM's theory and data could be enhanced. With an increasing emphasis on regional development, China's migration patterns might alter so that former farmers gravitate more so to regional inland cities and less so to cities of the eastern seaboard.

The version of SinoTERM we have presented in this study has many potential applications. For example, productivity studies could focus on particular sectors in particular regions, such as animal husbandry in Inner Mongolia. Such a study might combine land degradation issues with improved livestock management.

Nevertheless, it is likely that further development of SinoTERM will entail enhancements to deal with particular issues. Such enhancements might include satellite water accounts and additional theory to deal with water allocation. Modelers could add emissions accounts to model greenhouse gas scenarios. The development of fiscal accounts would allow users to represent the revenues and expenditures of different tiers of government, and model issues such as allocation of regional education and health resources, or regional agricultural R&D. Enhancements to SinoTERM might include more elaborate factor mobility possibilities so as to model the switch by farmers between different crops in response to changing relative input and output prices. We and our colleagues at the Centre of Policy Studies have developed each of these enhancements for various national and sub-national CGE models in response to policy issues.

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