A GTAP Historical simulation from 2004 to 2014

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CONTENTS

Summary including main results

(1) Historical simulations conducted with CGE models can reveal movements across a period in a wide variety of otherwise unobservable preference and technology variables.

(2) This paper describes an historical simulation from 2004 to 2014 for the GTAP model.

(3) As shown in Table S1 below, our GTAP historical simulation reveals worldwide preference/technology shifts: against the use of natural fibres (Plant fibres and Wool) in the production of Textiles; against Forestry and Paper & paper products; against Coal but in favor of Oil and Gas; against Petroleum consistent with improved efficiency in cars and against Electricity consistent with improved efficiency of electrical equipment; against direct consumption of most farm products and in favor of consumption of processed food products; and in favor of Apparel, Leather products, Motor vehicles, Electronic equipment, Air transport and Financial intermediation.

Table S1. Average annual percentage worldwide preference/technology shifts for 2004 to 2014 derived from a GTAP historical simulation*

	Com	Description			Com	Description	
1	pdr	Paddy rice	-0.66	30	lum	Lumber	-0.03
2	wht	Wheat	-1.67	31	ppp	Paper & p prods	-0.42
3	gro	Other grains	-0.47	32	p_c	Petroleum & coke	-1.39
4	v_f	Vegetables &fruit	-1.34	33	crp	Chem rubber prods	0.89
5	osd	Oil seeds	0.05	34	nmm	Non-met minerals	0.72
6	c_b	Cane & beet	0.22	35	i_s	Iron & steel	0.48
7	pfb	Plant fibres	-5.77	36	nfm	Non-ferrous metals	0.36
8	ocr	Other crops	0.72	37	fmp	Fab metal prods	0.33
9	ctl	Cattle	-0.92	38	mvh	Motor vehicles	0.92
10	oap	Other animal prods	-1.03	39	otn	Other transp equip	0.74
11	rmk	Raw milk	-0.68	40	ele	Electron equip	0.63
12	wol	Wool	-6.03	41	ome	Other mach & equip	-0.09
13	frs	Forestry	-3.05	42	omf	Other manu	1.33
14	fsh	Fishing	-1.25	43	ely	Electricity	-0.56
15	coa	Coal	-0.69	44	gdt	Gas distribution	-0.74
16	oil	Oil	0.35	45	wtr	Water	0.03
17	gas	Gas	1.14	46	cns	Construction	-0.11
18	omn	Other mining	-0.57	47	trd	Trade	-0.73
19	cmt	Cattle meat	0.27	48	otp	Other transport	0.38
20	omt	Other meat	1.05	49	wtp	Water transport	-0.18
21	vol	Vegetable oils	1.50	50	atp	Air transport	2.69
22	mil	Milk products	0.84	51	cmn	Communications	0.41
23	pcr	Processed rice	-0.85	52	ofi	Oth financ intermed	0.77
24	sgr	Sugar	-0.41	53	isr	Insurance	0.00
25	ofd	Other food	1.23	54	obs	Other bus services	0.16
26	b_t	Bev & tobac prods	1.17	55	ros	Rec & oth services	-0.57
27	tex	Textiles	0.23	56	osg	Other service govt	-0.69
28	wap	Apparel	1.10	57	dwe	Dwellings	0.28
29	lea	Leather	1.11			**Average**	**0.00**

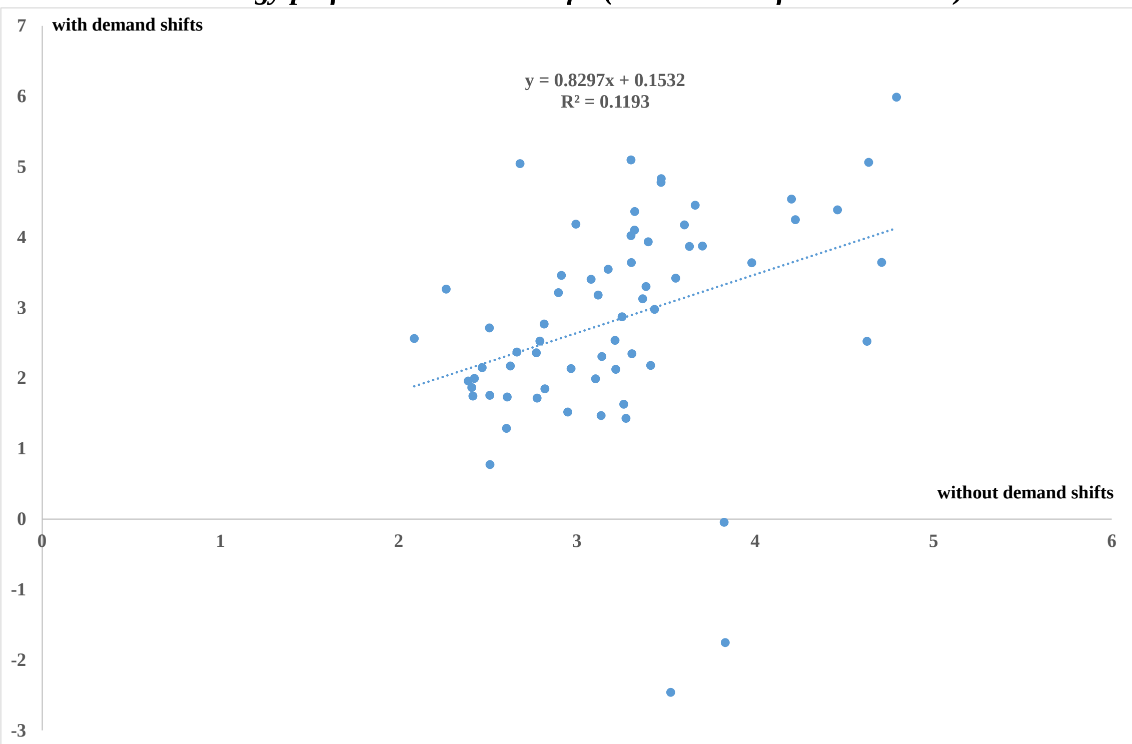
* *These are annualized results derived from the 10-year results for wldout_sh in step 15 in Table 2.6, normalized so that they average zero.*

(4) We used these preference/technology shifts in a baseline simulation for 2014 to 2017. Introduction of these shifts had a radical effect on the projected industrial composition of economic activity in all regions. This is illustrated for the world in Figure S1 below. We conclude that baselines relying only on macro projections are unlikely to give a useful picture of industry structure.

(5) Our baseline simulations were performed with GTAP-RD, the latest dynamic version of GTAP. However we needed to make minor changes to GTAP-RD. These are documented with relevant GEMPACK code in subsection 3.1.

(6) There are several directions in which the research in this paper could be taken. These include:
   (a) the introduction to the historical simulation of movements in additional variables;
   (b) the conduct of a decomposition simulation in which preference/technology shifts estimated *endogenously* in the historical simulation are fed back into the model in an analysis of the relative quantitative significance of different causation factors in economic change;
   (c) the conduct of updating exercises for the GTAP database to years beyond 2017 using trends from the historical simulation supplemented by contemporary data for macro and other variables;
   (d) the conduct of a validation exercise in which projections to 2014 using an historical simulation for 2004 to 2011 are checked against the GTAP data for 2014; and
   (e) the development of a trade baseline built around projections of trade matrices showing flows of each commodity between each pair of regions.

Figure S1. Percentage baseline growth rates for world commodity outputs with and without technology/preference demand shifts (world results from Table 3.1)



1. Introduction

This paper presents an historical simulation for 2004 to 2014 with the GTAP model.[1] To our knowledge this is the first historical simulation in a multi-region global model.[2]

Background

In a CGE historical simulation, we set up the model with a database for an historical year t, 2004 in this project. Then we compile data on movements in a selection of the model's variables from year t to year $t+\tau$. In this project year $t+\tau$ is 2014. Next, we treat these variables as exogenous and shock them with their observed movements.

The original motivation for historical simulations was as an updating technique for input-output tables. Working for the U.S. International Trade Commission in the early 2000s, we were faced with the problem that the latest published input-output table to support detailed CGE modeling of the U.S. economy was for 1992. However, there was comprehensive data on movements beyond 1992 in: macro variables; exports and imports by commodity; public and private consumption by commodity; employment and investment by industry; and an array of factor and commodity prices. By introducing these movements as exogenous shocks to USAGE model, we produced a complete 500-sector input-output database for 1998 that was consistent with the published values for all these variables.[3]

Many observed variables are naturally endogenous in CGE simulations. In historical simulations they must become exogenous so that we can shock them with their observed movements. Correspondingly, we must endogenize variables that are naturally exogenous. For example, assume that we observe the movements in: consumption and production of tobacco products; tax rates applying to tobacco products; wage rates and employment in the production of tobacco products; and household incomes. We accommodate this information in an historical simulation by endogenizing a tobacco-products preference variable in the household utility function and productivity variables in the tobacco-products production function. Thus, in addition to being an updating technique, historical simulations produce a major by-product: estimates of changes in preferences and technologies.

Estimates of changes in preferences and technologies can be used in two main ways: in decomposition studies and in baseline forecasting. Decomposition studies are concerned with explaining historical developments in the structure of the economy in terms of driving factors such as changes in preferences and technologies. Estimates of these changes from an historical simulation are fed back into the model as exogenous driving factors in a decomposition simulation. In baseline forecasting, trends in preferences and technologies estimated from an historical simulation are projected forward.

This paper

In performing a GTAP historical simulation we faced two challenges centred on data and closures.

GTAP provides complete, comparable input-output databases for 2004 and 2014. Using these databases we can compute immediately what happened between these two years to the *values* in each region of macro variables; public and private consumption by commodity; wagebills and returns to capital by industry; and intermediate inputs by commodity and

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[1] GTAP is the world's best known and most widely applied global CGE model. The original version is set out in Hertel (1997). Later versions are in Corong *et al.* (2017) and Aguiar *et al.* (2019).

[2] The technique of historical simulation applied in a single country CGE model was established in Australia, see for example, Dixon *et al.* (2000a&b) and Dixon and Rimmer (2002).

[3] See Dixon and Rimmer (2004) and Dixon *et al.* (2013).

industry. We can also compute *values* of trade flows by commodity between each pair of regions. This gives us an almost overwhelmingly rich database for deriving preference and technology changes in an historical simulation, except for one problem. There is no *quantity* data. The data are in values expressed in U.S. dollars converted from national currencies at official exchange rates. However, preference movements are about changes in *quantities* of commodities purchased by households at given prices and disposable incomes, and technology movements are about changes in *quantities* of inputs per unit of output in each industry.

Our previous report (Dixon and Rimmer, 2020, May 30) showed how we tackled the quantity issue for macro variables by using national accounts data for real GDP, real consumption, etc for each region. In the current paper, we access data on quantity output movements for about 60 per cent of the GTAP commodities.

The closure challenge is to find suitable naturally exogenous variables to be endogenized so that we can introduce observed movements in naturally endogenous variables. In our previous report, we accommodated observed movements in macro variables in our historical simulation by endogenizing import/domestic preference twists, multi-factor productivity movements and relative rates of technical progress in traded and non-traded industries (the Balassa-Samuelson effect). In this report we develop the historical simulation further by accommodating quantity movements in world outputs of commodities by endogenizing commodity-specific preference changes by households and intermediate-input technology changes by industries.

In the previous report we described 12 steps in the development of the historical simulation. Here we undertake a further 3 steps. In each step, we introduce the observed movements in a small number of variables. Then we compute the solution and compare it with that from the previous step. In this way can we isolate problems that become apparent in one step to data and closure changes introduced in that step. We interpret the results at each step in detail. This not only enables us to identify problems, but also to plan the next step.

The rest of the paper is organized as follows. In subsection 1.1 we recap the material from our previous report covering steps 1 to 12. Our objective is to make the current paper self-contained. Then in section 2 we describe steps 13 to 15. Step 13 introduces data on movements in values of world output by commodity. Step 14 introduces data on quantity movements in world commodity outputs. Step 15 revises and extends the data input from step 14 in light of detailed interpretation of results from both steps 13 and 14. In section 3 we demonstrate the application of results from the historical simulation to baseline forecasting by taking estimated preference and technology trends into a GTAP-RD baseline simulation[4] for 2014 to 2017. Concluding remarks are in section 4. Data sources and spreadsheet workbooks are described in appendix 1.

1.1. Recap of the story from the May 30 report

In the report of May 30 (Dixon and Rimmer, 2020 May), we described the first twelve steps in our historical simulation. Here we provide a recap so that this paper will be self contained.

In the first 12 steps we took into the historical simulations movements between 2004 and 2014 for each region in the following:

- employment and population;
- real GDP;

[4] GTAP-RD is the latest dynamic version of GTAP, see Aguiar *et al.* (2019 and 2020).

- nominal GDP expressed in $US converted from national currencies at the average exchange rate through 2004 and through 2014;
- nominal household consumption;
- nominal public consumption;
- nominal gross investment;
- nominal imports;
- nominal exports;
- capital stocks in real terms;
- the price indexes for oil and gas; and
- fob values for selected manufacturing exports by region.

Most of these observed movements can be seen in the shaded columns of Tables 1.1 to 1.3 (reproduced here from the May 30 report). The unshaded columns in these tables show movements in other variables calculated endogenously in the final simulation of that report (Step 12).

Given the data inputs for real GDP, employment and capital (first 3 columns of Table 1.1), the historical simulation implies exceptionally rapid primary-factor productivity growth in China, India and South Korea [column (6) of Table 1.1]. At the other extreme, Saudi Arabia, Mexico, UK and Rest of EU experienced reductions in primary-factor productivity. For the U.S., primary-factor productivity grew, but at a slow rate (4.53 per cent for the decade, or about 0.4 per cent a year).

Rapid primary-factor productivity growth for China, India and South Korea not only contributed directly to GDP growth, but also indirectly by stimulating capital growth. Consistent with rapid growth in primary-factor productivity and declining required rates of return on capital (to be discussed shortly), these three countries had enormous increases in their capital/labor ratios [column (4)].

Table 1.1. Deriving primary factor technical change: percentage changes between 2004 and 2014

	Real GDP	Employ -ment	Capital	K/L ratio	Rel price of GDP[a]	Prim-factor tech change		
						total	Non-traded	Traded
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
USA	17.39	3.44	28.08	23.82	-11.20	4.53	16.13	-12.77
Canada	20.75	8.53	32.03	21.65	6.58	6.95	8.19	5.26
Mexico	23.28	24.82	42.08	13.83	0.88	-9.53	-12.88	-4.83
China	160.10	5.27	212.48	196.84	52.38	66.07	-35.60	664.45
Japan	6.04	-2.44	11.05	13.83	-31.39	-0.52	140.07	-57.82
SKorea	45.63	-3.34	59.04	64.54	-6.48	25.67	49.33	4.53
India	109.37	9.00	157.68	136.40	-0.07	40.58	37.90	44.22
France	10.23	3.07	24.27	20.57	-11.75	0.67	24.12	-22.90
Germany	14.44	4.31	16.57	11.75	-11.57	5.27	36.02	-16.38
UK	14.20	9.02	20.30	10.35	-15.97	-2.24	51.38	-39.07
RoEU	7.27	-3.09	26.19	30.21	-5.64	-2.81	9.77	-15.86
SaudiArabia	49.11	54.09	112.60	37.97	44.60	-15.46	17.36	-27.25
RoW	52.61	26.24	48.07	17.29	31.75	22.02	-12.55	88.39

[a] Real exchange rate movement

Table 1.2. Factor prices and rates of return: percentage changes between 2004 and 2014

	Wage rate*	Rental rate*	Price of capital goods*	Rate of return
	(1)	(2)	(3)	(4)
USA	40.43	-3.79	16.18	-38.09
Canada	64.23	11.79	47.02	-47.18
Mexico	39.32	6.17	26.26	-20.36
China	630.61	-20.65	72.76	-79.41
Japan	4.23	-22.43	2.03	-38.47
SKorea	120.75	-15.50	37.38	-63.28
India	227.03	-52.68	24.27	-86.24
France	32.66	-5.83	27.98	-51.63
Germany	33.22	11.13	24.60	-18.26
UK	16.55	0.69	5.40	-7.10
RoEU	56.11	-5.91	27.72	-37.72
SaudiArabia	98.05	6.10	47.42	-35.21
RoW	128.26	52.96	76.05	-18.36

* These are prices in $US, converted from local currency at the average exchange rates through 2004 and through 2014

Column (5) of Table 1.1 shows movements in real exchange rates. The real exchange rate movement for a region is the percentage change in its price level converted to a common currency and then compared with an average over all regions. [5] Between 2004 and 2014, there were sharp real appreciations for China, Saudi Arabia and Rest of World. By contrast, the U.S., Japan, France, Germany and UK had double digit percentage declines in their real exchange rates.

The first line of explanation in our historical simulation of movements in real exchange rates is the Balassa-Samuelson effect[6]. According to this theory, a region will experience real appreciation if it has rapid productivity growth in traded-goods industries relative to non-traded. As can be seen from columns (7) and (8) of Table 1.1, this is the mechanism in our historical simulation that explains real appreciations for China and Rest of World. Similarly, according to Balassa-Samuelson, a region will experience real devaluation if it has slow productivity growth in traded-goods industries relative to non-traded. This mechanism is used in our historical simulation to accommodate the declines in the real exchange rates of the U.S., Japan, France, Germany and the UK.

But what about Saudi Arabia which had, according to our historical simulation, a large real appreciation but slow productivity growth in traded-goods industries relative to non-traded? In our historical simulation, real exchange rate appreciation for Saudi Arabia is explained by the massive increase between 2004 and 2014 in the prices of its principal exports, oil and gas.

Column (4) of Table 1.2 shows that our historical simulation implies reductions in rates of return on capital in all regions. Rates of return are the ratio of rental rates on capital to the asset price of capital less the rate of depreciation. The rate of depreciation is fixed at 4 per

[5] The percentage movement in the real exchange rate for region r between two years [rexch(r)] is defined by $\text{rexch(r)} = [\text{p(r)} + \text{e(r)}] - \sum_s \text{S(s)} * [\text{p(s)} + \text{e(s)}]$ where p(r) is the percentage change in the price level (GDP deflator) in region r, e(r) is the percentage change in r's exchange rate ($US per unit of r's currency) and the S(s)'s are a weighting scheme (shares in world GDP).

[6] See Balassa (1964) and Samuelson (1964).

Table 1.3. Nominal GDP & expenditure-side components in $US, and import-domestic preference twists (percentage changes between 2004 and 2014)

	GDP[1]	Private cons.	Public cons.	Investment	Exports	Import	Imp-Dom twist[2]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
USA	41.33	45.79	38.41	26.58	80.97	61.01	-13.68
Canada	74.33	77.66	82.95	96.73	48.19	74.84	0.63
Mexico	68.49	71.81	93.60	68.47	110.50	133.20	143.10
China	433.09	403.25	423.41	484.35	244.78	227.09	-25.73
Japan	-1.28	2.21	9.13	-4.31	33.53	69.56	-3.11
SKorea	84.52	94.59	86.42	76.13	117.29	130.39	5.31
India	183.05	188.00	195.71	217.02	244.32	318.30	89.81
France	31.90	33.54	40.01	35.50	51.94	66.70	22.21
Germany	37.21	30.81	44.13	44.00	71.83	73.05	23.92
UK	30.13	32.28	29.52	23.09	44.48	42.00	-23.54
RoEU	37.22	39.86	44.68	17.95	71.30	66.62	19.45
SaudiArabia	191.35	182.75	205.38	252.12	202.51	261.21	41.32
RoW	171.82	167.13	190.20	203.37	134.00	149.65	-7.45

[1] These are values in $US, converted from local currency at the average exchange rates through 2004 and through 2014.
[2] An import-domestic twist of *x* per cent means that the ratio of quantities of imports to domestic goods absorbed in a region increased by *x* per cent more than can be explained by changes in relative prices and the composition of demand across industries, households, government and capital creators.

cent in all regions. The historical simulation shows reductions in rental rates relative to the costs of creating capital [columns (2) and (3) of Table 1.2].

Reductions in rates of return on capital are consistent with strong growth in global savings associated with extremely rapid growth in the share of the world economy accounted for by China which has a very high average propensity to save. Strong growth in the availability of investible funds (global savings) relative to investment opportunities reduces rates of return required by lenders, allowing lower-rate-of-return investment projects to go ahead.

The historical simulation implies that reductions in rates of return were particularly pronounced for India and China. This is consistent with these economies becoming more open and being considered safer destinations for investment by both foreign and local savers. Reductions in rates of return and fast productivity growth supported rapid wage growth in both these countries [column (1) in Table 1.2].

Table 1.3 shows the data input for movements in nominal GDP and its expenditure-side components (C, G, I, X and M). For most regions, trade, both X and M, grew rapidly relative to GDP. The leading exception was China. While the $US values of Chinese exports and imports increased by over 200 per cent between 2004 and 2014, these increases did not match the increase in the $US value of Chinese GDP (433 per cent).

Rapid growth in imports for most regions is explained in our historical simulation principally by a twist in preferences in favor of imports relative to domestic varieties. Via exchange rate adjustments, rapid growth in imports generally creates rapid growth in exports.

Preference twists in favor of imports are consistent with improvements in communications leading to greater awareness in each region of products produced in other regions. In the case of China, the preference twist shown in Table 1.3 is against imports. This may indicate that Chinese producers have increased their ability to satisfy demands by Chinese consumers for high quality goods that were previously imported.

In the case of the U.S., our simulation shows a moderate twist against imports. This is despite growth in the share of imports in GDP, 61 per cent growth in imports compared with 41 per cent growth in GDP. The explanation is that the composition of U.S. GDP switched towards import-intensive activities (private consumption and the production of exports) and away from low-import activities (investment and public expenditure). This compositional switch caused an increase in imports relative to GDP even with a preference shift by households and industries away from imports.

2. Introducing micro data to the historical simulation: world outputs and prices for GTAP commodities

As outlined in subsection 1.1, the first 12 steps in our historical simulation were primarily about introducing data for macro variables, the only exceptions were the prices of oil and gas, and the values of a selection of manufactured exports by region.

In this section we describe three further steps (13 to 15) in which we introduce data on industry/commodity variables at the regional level.

2.1. Step 13: Taking in movements in values of world outputs of commodities and discovering world-wide average shifts in household and government preferences and in commodity-input-using technology variables for industries

From the GTAP databases for 2004 and 2014, we calculated the percentage changes in the values of world output of each of the 57 GTAP commodities. We absorbed this information in the historical simulation by endogenizing a twist in preferences by households, governments and industries throughout the world towards or against the use of each commodity. For example, if the increase in the value of the output of a commodity between 2004 and 2014 was large relative to what could be explained by GTAP taking account of movements already introduced in macro variables, then the historical simulation implied that there was a twist in preferences towards that commodity. We refer to this twist as a demand shift.

2.1.1. Technicalities of absorbing movements in the values of world outputs

Readers who are not concerned with the GEMPACK programming of GTAP can skip this subsection, and move directly to the discussion of results starting in subsection 2.1.2.

So that we could take in information on values of world outputs, we added an equation to GTAP defining percentage changes in these variables:

```
(All,i,TRAD_COMM) sum(r,REG, VOM(i,r))*v_wldout(i)
                          = sum(r,REG, VOM(i,r)*v_vom(i,r) );        (2.1)
```

It was also convenient to add equations defining percentage changes in prices and quantities of world outputs of commodities:

```
(All,i,TRAD_COMM) Sum(r,REG, VOM(i,r))*pworld(i)
                          = Sum(r,REG, VOM(i,r)*pm(i,r));            (2.2)

(All,i,TRAD_COMM) qworld(i) = v_wldout(i) - pworld(i);               (2.3)
```

In these equations,

VOM(i,r) is the market value of commodity i produced in region r;
v_vom(i,r) is the percentage change in the market value of commodity i produced in region r;

pm(i,r) is the percentage change in the market price of commodity i produced in region r; and

v_wldout(i), pworld(i) and qworld(i) are the percentage changes in the values, prices and quantities of world outputs of commodity i.

In general we absorb the information for commodity i through an endogenous shift in a variable [wldout_sh(i)] that imparts an equal percentage change to the quantity demand for commodity i by all users in all regions.

The key equations for understanding our approach are:

(**all**,i,PROD_COMM) v_wldoutobs(i) = v_wldout(i) + f_wldout(i); (2.4)

(**all**,i,TRAD_COMM)(**all**,j,PROD_COMM)(**all**,r,REG) afall(i,j,r)
= - wldout_sh(i) + f_afall(i,j,r); (2.5)

(**all**,i,TRAD_COMM)(**all**,r,REG) a3com(i,r) = wldout_sh(i)+shift_c(r) + f_a3com(i,r); (2.6)

(**all**,i,TRAD_COMM)(**all**,r,REG) f_qg(i,r) = wldout_sh(i)+shift_g(r) + ff_qg(i,r); (2.7)

Equation (2.4) relates observed world output of commodity i [v_wldoutobs(i), computed from the GTAP databases for 2004 and 2014] to simulated output [v_wldout (i)] and a shift variable [f_wldout(i)]. Initially, the shift variable is endogenous. With the introduction of the observed movements in world outputs we exogenize the shift variable.

Equation (2.5) relates the technology variable for the use of commodity i by industry j in region r to two shift variables. Initially, the technology variable is exogenous, the 3-dimension shift variable [f_afall(i,j,r)] is endogenous and wldout_sh(i) is exogenous.

Equations (2.6) and (2.7) relate the preference variables in region r for commodity i for households [a3com(i,r)] and government [f_qg(i,r)] to shift variables. Initially, the preference variables are exogenous. The higher dimension shift variables [f_a3com(i,r) and ff_qg(i,r)] are endogenous and the other shift variables are exogenous.

Adopting the convention that variables on the left-hand side of a swap statement go endogenous, we bring in the observed movements in values of world outputs for commodities by performing the following swaps:

swap wldout_sh(TRAD_COMM) = f_wldout(TRAD_COMM);
swap afall(TRAD_COMM,PROD_COMM,REG) =
f_afall(TRAD_COMM,PROD_COMM,REG);
swap a3com = f_a3com;
swap shift_c = ave_a3com;
swap f_qg = ff_qg;
swap shift_g= ave_f_qg;

With f_wldout set on zero, the first swap forces the simulated value of world output for each commodity to be equal to the observed value.

The second swap allows the technology variables for the use of commodity i to be driven by wldout_sh(i), see equation (2.5).

The third and fourth swaps allow household preference variables for the consumption of commodity i to be driven by wldout_sh(i) with an endogenous adjustment [shift_c(r)] to allow the endogenous preference variables in each region to add to an exogenous level [ave_a3com(r)]. Without an exogenous absolute level for the preference variables they are indeterminate.

The fifth and sixth swaps play analogous roles for government.

2.1.2. Results from absorbing movements in the values of world outputs

Results for step 13 with comparative results from step 12R are set out in Table 2.1 and 2.2. As explained in the footnote below Table 2.1, the step 12R simulation is a slightly revised version of the step 12 simulation presented in our report of May 30.

Table 2.1 shows that the introduction of data for the values of world outputs of commodities has relatively minor effects on macro variables at the regional level. One noticeable feature of the comparison is that total primary factor technical change in all regions is lower in step 13 than in step 12R. This needs explanation. In the two steps, real GDP and primary factor inputs are the same. So how can primary-factor productivity be different? The answer is that in step 13 the volume of world production of intermediate inputs grows less quickly than in step 12R. Consequently, in step 13 there is saving of intermediate inputs relative to that in step 12R. But the total factor productivity movement in each region in step 13 must be approximately the same as that in step 12R. This explains why primary-factor productivity growth is less in step 13 than in step 12R.

By comparing the two panels in Table 2.2, we can see the effects on simulated world prices and world *quantity* outputs of introducing the GTAP data on world *values* of commodity outputs. We work through the results for 17 commodities, starting with Paddy rice (pdr). The aim is to understand how the model is working with the historical closures used in steps 12R and 13. At the same time, we will be laying the foundations for improving the realism of the demand-shift variables in the next step.

Paddy rice (pdr)

In the movement from step 12R to step 13, the percentage increase between 2004 and 2014 in the value of world output of Paddy rice is reduced from 219.56 to the observed percentage increase of 140.68. This is accommodated in step 13 by reductions in the percentage increases in both price and quantity (104.64 and 56.55 per cent in step 12R to 76.37 and 36.66 per cent in step 13).

With primary-factor technology variables being largely set in earlier steps, we anticipated that the introduction of value data for output would have relatively minor effects on costs per unit of output and therefore prices. Thus, with the value of Paddy rice output being cut by 24.68 per cent as we go from step 12R to step 13 [-24.68 = 100*(2.4068/3.1956 -1)], our first guess was that the quantity would be cut by approximately 24.68 per cent. But in fact the quantity cut is only 12.71 per cent [-12.71 = 100*(1.3666/1.5655-1)]. As the quantity is cut, we found that the simulated price falls mainly because the price of land used in producing Paddy rice falls. This reduces the simulated price of Paddy rice in step 13 relative to step 12R, limiting the reduction in quantity.

The reduction in the quantity of Paddy rice is accommodated in step 13 by a preference/technology shift (-41.81 per cent) against the use of Paddy rice. This seems a large shift given that output is down by only 12.71 per cent. However, recall that the price of Paddy rice is lower in step 13 than in step 12R and that the shift must overcome the demand stimulation produced by the price reduction.

*Table 2.1. **Real exchange rate movements & primary factor technical changes after 12 steps (revised)* and 13 steps: percentage changes between 2004 and 2014***

	Results **after step 12R**				Results **after step 13**			
	Rel price of GDP	Prim-factor tech change			Rel price of GDP	Prim-factor tech change		
		Total	Non-traded	Traded		Total	Non-traded	Traded
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
USA	-11.20	4.66	15.67	-12.04	-11.20	1.51	13.24	-15.69
Canada	6.58	5.81	3.45	10.33	6.58	2.97	-0.46	8.95
Mexico	0.88	-8.68	-18.37	7.22	0.88	-10.16	-19.31	3.32
China	52.38	64.47	-33.39	576.10	52.38	59.71	-34.76	493.23
Japan	-31.39	-0.54	143.51	-58.16	-31.39	-2.09	139.07	-57.88
SKorea	-6.48	25.81	50.31	4.14	-6.48	20.89	44.72	0.44
India	-0.07	40.36	37.16	44.37	-0.07	27.66	11.42	50.91
France	-11.75	0.75	23.67	-22.41	-11.75	-2.32	21.44	-25.45
Germany	-11.57	5.38	35.30	-15.85	-11.57	2.10	33.85	-19.47
UK	-15.97	-1.22	41.46	-34.56	-15.97	-3.91	36.03	-35.19
RoEU	-5.64	-2.75	8.80	-14.91	-5.64	-5.72	5.03	-17.12
SaudiArabia	44.60	-9.4	-37.15	14.10	44.60	-19.05	-52.56	18.60
RoW	31.75	16.66	-13.06	77.34	31.75	12.16	-18.46	75.00

* The productivity results in columns (2) – (4) are not the same as those in columns (6) – (8) of Table 1.1. This is because we made minor changes to the step 12 simulation from the version in our report of May 30. We refer to this new version of step 12 as step 12 revised, or step 12R. In the revised version, we:

(1) introduced a provisional price estimate for coal which is revised later in step 15;
(2) absorbed the price information for oil and gas (as well as coal) via endogenous world-wide production taxes rather than endogenous endowment movements, see discussion in subsection 2.2.1;
(3) exogenized the natural resource price for coal in Saudi Arabia to avoid a spurious negative value (Saudi Arabia doesn't produce coal);
(4) changed the household demand parameter INCPAR("pcr",r). We made this the same as the corresponding parameter for "ofd". Previously the pcr values had been close to zero leading to very low expenditure elasticities. We noticed this problem because later it generated an enormous preference shift towards "pcr".

Processed rice (pcr)

In the movement from step 12R to step 13, the percentage increase between 2004 and 2014 in the value of world output of Processed rice is increased from 156.07 to the observed percentage increase of 236.89. This is accommodated in step 13 by a massive increase in the percentage growth in quantity (from 49.84 per cent to 190.08 per cent). The price goes the other way (from 71.17 per cent to 16.30 per cent).

Why is price of Processed rice so much lower in step 13 than in step 12R? This is explained by a reduction in the cost to Processed rice of its principal input, Paddy rice. The -41.81 per cent technology shift against the use of Paddy rice means (unrealistically) that a unit of Processed rice can be produced with 41.81 per cent less input of Paddy rice while holding all other inputs to Processed rice constant. This is a major reduction in the cost per unit of Processed rice, which is accentuated further by the reduction in the price of Paddy rice.

With the price of Processed rice significantly reduced as we go from step 12R to step 13 and the value significantly increased, there must be a large percentage increase in the quantity. This is accommodated in step 13 by a very large preference/technology shift in favor of Processed rice (75.63 per cent).

In terms of the data and assumptions that we have made so far, our analysis of the Paddy rice and Processed rice results makes sense. However, these results are unrealistic. In light of our analysis here, we will revise our assumptions in the next step.

Raw milk (rmk) and Milk products (mil)

The results in Table 2.2 for Raw milk and Milk products exhibit similar (but less extreme) problems to those we saw for Paddy rice and Processed rice. As we go from step 12R to step 13, the value of the farm product, Raw milk, falls (from a percentage increase of 185.57 to 81.14), while at the same time, the value of the processed product, Milk products, rises (from a percentage increase of 78.66 to 110.47).

Thus in the transition from step 12R to step 13 we see: reductions in both the price and quantity of Raw milk; a preference/technology shift against Raw milk; a substantial increase in the quantity of Milk products; a reduction in the price of Milk products; and a preference/technology shift towards Milk products.

Cattle (ctl) and Cattle meat (cmt); Other animal prods (oap) and Other meat (omt)

These are two more examples of the same story. As we go from step 12R to 13, there is a decrease in the value of the farm product (Cattle, Other animal prods) and an increase in the value of the processed product (Cattle meat, Other meat). This leads to: reductions in both the price and quantity of the farm product; a preference/technology shift against the farm product; a substantial increase in the quantity of the processed product; a reduction in the price of the processed product; and a preference/technology shift towards the processed product.

Cane & beet (c_b) and Sugar (sgr);

The story for these two products is the same again except for one minor difference. In the transition from step 12R to 13, the quantity of the farm product, Cane & beet, rises (from an increase of 41.31 per cent in step 12R to 46.06 per cent in step 13). Nevertheless, the price of the Cane & beet falls (from an increase of 78.47 per cent to 65.65 per cent), and the rest of the previous stories falls into place.

As with other farm products, we found that the price of Cane & beet falls as we go from step 12R to 13 because the price of land used in Cane & beet falls. But how can the price of land fall when the produced quantity of Cane & beet rises, implying an increase in the use of land for Cane & beet? The answer is that the price of agricultural land in general falls between steps 12R and 13. But for Cane & beet, the decline in the price of land is relatively small. Thus, more land can be allocated to Cane & beet to support increased output even with a reduction in the rent paid by Cane & beet farmers.

Oil (oil) and Petroleum & coke (p_c)

In the transition from step12R to 13 the value of the primary product, Oil, falls (from an increase of 251.89 per cent in step 12R to 193.87 per cent in step 13). Because the price of Oil is fixed in the two steps at its observed increase (167.8 per cent) the quantity of Oil must fall between steps 12R and 13 (from an increase of 31.67 per cent to 9.83 per cent).

Table 2.2. Percentage movements between 2004 and 2014 in world prices, quantities, values and demand shifts for GTAP commodities: step 12R (before the introduction of commodity value data) compared with step 13 (after the initial introduction of these data)

			Step 12R				Step 13			
			price (1)	quantity (2)	value (3)	demand sh (4)	price (5)	quantity (6)	value (7)	demand sh (8)
	Com	Description	pworld	qworld	v_wldout	wldout_sh	pworld	qworld	v_wldout	wldout_sh
1	pdr	Paddy rice	104.64	56.55	219.56	0.0	76.37	36.66	140.68	-41.81
2	wht	Wheat	67.88	49.67	150.85	0.0	60.01	50.82	140.94	-1.90
3	gro	Other grains	67.55	44.96	142.51	0.0	69.32	72.91	192.06	14.26
4	v_f	Vegetables &fruit	79.46	49.29	167.43	0.0	70.32	44.72	146.09	-7.55
5	osd	Oil seeds	73.28	47.39	154.97	0.0	65.87	60.27	165.31	-14.29
6	c_b	Cane & beet	78.47	41.31	151.81	0.0	65.65	46.06	141.57	-19.24
7	pfb	Plant fibres	76.56	62.33	185.99	0.0	63.08	40.58	128.93	-27.45
8	ocr	Other crops	74.40	22.85	114.06	0.0	57.39	-1.85	54.52	-21.81
9	ctl	Cattle	65.09	36.86	125.66	0.0	56.48	33.01	107.91	-18.48
10	oap	Other animal prods	73.03	51.85	162.29	0.0	61.19	32.43	113.23	-26.92
11	rmk	Raw milk	107.07	38.16	185.57	0.0	87.21	-3.28	81.14	-39.44
12	wol	Wool	69.80	73.13	193.29	0.0	51.97	47.63	124.06	-25.42
13	frs	Forestry	15.48	59.70	84.33	0.0	19.92	68.09	101.43	5.25
14	fsh	Fishing	28.34	49.83	92.16	0.0	52.97	79.37	173.84	15.85
15	coa	Coal	100.00	61.58	222.32	0.0	100.00	78.33	255.43	10.42
16	oil	Oil	167.80	31.67	251.89	0.0	167.80	9.83	193.87	-35.48
17	gas	Gas	167.80	22.93	228.71	0.0	167.80	-13.51	131.93	-33.80
18	omn	Other mining	27.95	67.81	114.50	0.0	38.14	120.53	203.96	17.60
19	cmt	Cattle meat	47.11	21.46	78.58	0.0	36.79	56.63	114.03	19.85
20	omt	Other meat	50.38	19.53	79.65	0.0	34.31	76.53	136.78	35.81
21	vol	Vegetable oils	48.42	32.30	96.18	0.0	46.88	113.83	213.26	37.32
22	mil	Milk products	46.29	22.20	78.66	0.0	32.98	58.43	110.47	19.42
23	pcr	Processed rice	71.17	49.85	156.07	0.0	16.30	190.08	236.89	75.63
24	sgr	Sugar	45.65	30.05	89.27	0.0	37.35	88.07	157.89	29.12
25	ofd	Other food	46.44	20.57	76.48	0.0	49.94	38.81	107.93	13.98
26	b_t	Bev & tobac prods	39.23	22.33	70.23	0.0	40.51	41.01	97.96	14.49
27	tex	Textiles	37.35	40.43	92.72	0.0	32.09	61.67	113.33	-0.35
28	wap	Apparel	34.24	27.86	71.56	0.0	35.49	84.32	149.34	41.60
29	lea	Leather	43.08	30.61	86.75	0.0	45.83	61.76	135.55	15.23
30	lum	Lumber	35.36	23.82	67.53	0.0	36.86	18.85	62.62	-1.79

Observed (data driven) entries are shaded

Table 2.2 continues …

Table 2.2 continued …

			Step 12R				Step 13			
			price	quantity	value	demand sh	price	quantity	value	demand sh
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Com	Description	pworld	qworld	v_wldout	wldout_sh	pworld	qworld	v_wldout	wldout_sh
31	ppp	Paper & p prods	41.48	26.57	78.97	0.0	39.54	21.21	69.08	-3.74
32	p_c	Petroleum & coke	139.03	31.66	214.14	0.0	69.84	70.29	188.55	19.51
33	crp	Chem rubber prods	45.42	37.88	100.32	0.0	44.23	50.33	116.58	5.04
34	nmm	Non-met minerals	39.90	46.13	104.24	0.0	44.87	75.09	153.22	23.27
35	i_s	Iron & steel	39.63	54.50	115.48	0.0	45.25	63.71	137.44	5.35
36	nfm	Non-ferrous metals	36.26	53.77	109.32	0.0	53.62	113.23	226.64	28.93
37	fmp	Fab metal prods	40.32	28.51	80.21	0.0	48.63	30.58	93.96	1.96
38	mvh	Motor vehicles	40.94	22.70	72.85	0.0	45.91	27.18	85.45	1.60
39	otn	Other transp equip	39.05	34.20	86.47	0.0	44.69	43.69	107.70	5.12
40	ele	Electron equip	32.39	40.20	85.47	0.0	36.79	46.39	100.08	2.71
41	ome	Other mach & equip	37.11	38.13	89.24	0.0	42.41	33.93	90.60	-3.98
42	omf	Other manu	29.85	34.30	74.29	0.0	33.92	53.99	106.01	13.71
43	ely	Electricity	51.70	47.48	123.44	0.0	46.99	37.95	102.62	-11.15
44	gdt	Gas distribution	34.13	25.95	68.85	0.0	28.10	10.99	42.16	-12.88
45	wtr	Water	34.57	39.74	87.90	0.0	36.20	32.33	80.12	-5.38
46	cns	Construction	42.01	45.31	106.15	0.0	47.92	31.30	94.07	-11.91
47	trd	Trade	34.42	37.18	84.27	0.0	37.21	22.40	67.87	-12.45
48	otp	Other transport	54.93	23.18	90.71	0.0	49.02	24.98	86.12	0.67
49	wtp	Water transport	50.01	48.24	122.09	0.0	40.35	28.30	79.95	-21.29
50	atp	Air transport	73.25	19.39	106.71	0.0	60.48	7.71	72.85	-10.34
51	cmn	Communications	23.64	39.70	72.63	0.0	26.06	37.20	72.87	-0.89
52	ofi	Oth financ intermed	26.55	36.46	72.60	0.0	30.27	39.02	80.97	2.51
53	isr	Insurance	39.22	16.78	62.54	0.0	40.28	12.24	57.42	-3.82
54	obs	Other bus services	40.65	17.13	64.68	0.0	41.78	12.55	59.53	-2.23
55	ros	Rec & oth services	34.55	33.95	80.10	0.0	33.31	20.62	60.74	-12.04
56	osg	Other service govt	38.89	28.48	78.34	0.0	41.52	21.87	72.39	-11.47
57	dwe	Dwellings	-6.87	67.24	55.79	0.0	-3.07	64.24	59.22	-2.33

Observed (data driven) entries are shaded

The value of the processed product, Petroleum & coke, also falls in the transition from step 12R to 13 (from an increase of 214.14 per cent to 188.55 per cent). There are three possible ways of accommodating the fall in value: (a) an increase in price that is more than offset by a decrease in quantity; (b) a reduction in both price and quantity; and (c) an increase in quantity that is more than offset by a decrease in price. Possibility (a) is highly improbable: there is no change in the price of the principal input. Both (b) and (c) are possible *a priori*. As it happens, (c) is the outcome. The price of Petroleum & coke falls reflecting oil-saving technical progress (a preference/tech shift of -35.48 per cent in the use of oil) while the quantity of Petroleum & coke rises sharply accommodated by a Petroleum & coke-using preference/tech shift of 19.51 per cent.

Electricity (ely)

Value for Electricity declines moderately as we go from step 12R to 13 (123.44 to 102.62). This is accommodated by moderate falls in both price and quantity. Price falls because the price of an important input, Petroleum & coke, falls while the prices of other important inputs, coal, oil and gas are held constant. The fall in the price of Electricity is not sufficient to account for all of the fall in value. Thus, there is also a fall in quantity, accommodated by an Electricity-saving preference/tech shift (-11.15 per cent).

Water transport (wtp) and Air transport (atp)

For both these commodities, value falls in the transition from step 12R to 13. Price also falls, reflecting the reduction in the price of a principal input, Petroleum & coke. In both cases, the fall in price is insufficient to accommodate the fall in value. Thus, in both cases quantity falls, accommodated by negative preference/tech shifts.

Apparel (wap) and Leather (lea)

For both these commodities, the observed value for output used in step 13 is considerably higher than the value generated in step 12R. In both cases there is little change in price. Thus, the transition from step 12R to step 13 requires large increases in quantity accommodated by positive shifts in preference/technology variables (41.60 and 15.23 per cent).

Apparel and Leather are predominantly consumer goods. The strong positive preference/tech shifts revealed in step 13 prompted us to look at household expenditure elasticities for these commodities. We found that these are around 0.8 to 0.9. This seems too low. We plan to increase these elasticities and expect to see a reduction in the preference/tech shifts in the next step.

2.2. Step 14: Taking in movements in quantities of world outputs for selected commodities and improving the estimates of world-wide average shifts in household and government preferences and in commodity-input-using technology variables for industries

Using a wide variety of sources, we assembled data on growth between 2004 and 2014 in the quantity of world output for 31 of the 57 GTAP commodities. The 31 growth percentages are the shaded entries in column (6) of Table 2.4. A description of the data sources is in Appendix 1.

In this step we introduce these 31 quantity growth percentages to the historical simulation.

2.2.1. Technicalities of absorbing movements in quantities of world outputs

Readers who are not concerned with the GEMPACK programming of GTAP can skip this subsection, and move directly to the discussion of results starting in subsection 2.2.2.

So that we could take in information on quantities of world outputs, we changed the closure from that adopted in step 13 by the swap statement:

swap to_wld(c) = qworld(c) , for c∈COM31_OBS

where

COM31_OBS is the set of 31 commodities for which we have data on percentage quantity growth between 2004 and 2014;
qworld(c) is the percentage quantity growth for commodity c which is now set exogenously for c∈COM31_OBS; and
to_wld(c) is the percentage movement in a tax on the production of commodity c which applies uniformly across all regions. For c∈COM31_OBS, this tax rate is endogenous. It adjusts the world price of commodity c so that price *times* volume is compatible with the exogenously set value movement.

An obvious question is what happens to the tax revenue. Who spends it? With macro aggregates already determined exogenously in earlier steps, the introduction of this artificial production tax has no macro implications beyond affecting endogenously determined regional movements in average propensities to consume and distributions of national saving between households and government. Even if these endogenously determined variables are distorted by the introduction of the endogenous production tax, no damage is done. We do not use results for average consumption propensities for households or private/public distributions of national saving either in our interpretation of events between 2004 and 2014 or in projections based on trends from our analysis of this period.

Another question is why use a tax to move world prices into compatibility with observed values and quantities of world output. Why not use productivity variables to move prices? The simple answer is that using artificial production taxes is easier. We have already allowed endogenous movements in productivity variables to accommodate observed movements in macro price variables (the Balassa-Samuelson effect). We judged that introducing further productivity shifts at the industry level would cause potentially unstable solutions reflecting indeterminacies between the roles of different productivity variables in accommodating the macro and micro price targets.

In step 13, we exogenized the world prices of Coal (coa), Oil (oil) and Gas (gas). As indicated by the shading in column (6) of Table 2.4, these three commodities are in the set COM31_OBS. We can't simultaneously exogenize quantity, value and price. In this step we re-endogenize the world prices of Coal (coa), Oil (oil) and Gas (gas).

2.2.2. Results from absorbing movements in quantities of world outputs

The right-hand panels of Tables 2.3 and 2.4 show results for step 14. The left-hand panels show results from step 13. Comparison of the left and right panels shows the effects of the introduction of the observed quantity growth percentages for the commodities in COM31_OBS.

Table 2.3. Real exchange rate movements & primary factor technical changes after 13 steps and 14 steps: percentage changes between 2004 and 2014

	Results **after step 13**				Results **after step 14**			
	Rel price of GDP	Prim-factor tech change			Rel price of GDP	Prim-factor tech change		
		Total	Non-traded	Traded		Total	Non-traded	Traded
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
USA	-11.20	1.51	13.24	-15.69	-11.20	3.43	14.29	-12.88
Canada	6.58	2.97	-0.46	8.95	6.58	3.79	-1.88	13.99
Mexico	0.88	-10.16	-19.31	3.32	0.88	-8.85	-17.96	4.99
China	52.38	59.71	-34.76	493.23	52.38	61.58	-33.13	521.81
Japan	-31.39	-2.09	139.07	-57.88	-31.39	-0.47	126.7	-55.73
SKorea	-6.48	20.89	44.72	0.44	-6.48	23.97	48.29	2.82
India	-0.07	27.66	11.42	50.91	-0.07	36.93	39.38	34.14
France	-11.75	-2.32	21.44	-25.45	-11.75	-0.11	23.88	-23.67
Germany	-11.57	2.10	33.85	-19.47	-11.57	3.70	32.07	-16.35
UK	-15.97	-3.91	36.03	-35.19	-15.97	-2.12	33.73	-31.79
RoEU	-5.64	-5.72	5.03	-17.12	-5.64	-4.13	6.65	-15.58
SaudiArabia	44.60	-19.05	-52.56	18.60	44.60	-11.86	-41.63	17.21
RoW	31.75	12.16	-18.46	75.00	31.75	15.54	-13.52	73.63

Table 2.3 implies that the introduction of data for quantity movements of commodities has relatively minor effects on macro variables. Total primary-factor technical change in all regions is a little higher in step 14 than in step 13, compare columns (6) and (2). In step 14 there is increased use of intermediate inputs relative to that in step 13. With total-factor productivity growth in each region in step 14 having to be approximately the same as that in step 13, primary-factor productivity growth must be greater in step 14 than in step 13.

By contrast, Table 2.4 shows that the introduction of quantity data has major effects on commodity/industry variables. In discussing the results in Table 2.4, we are particularly concerned with demand shifts (wldout_sh). Movements in these variables are important for three reasons. First, they encapsulate much of what can be learnt from an historical simulation about changes in technologies and household preferences. Second, they help us pinpoint weaknesses in our model: clearly unrealistic results for demand-shift variables can alert us to unrealistic parameter settings. Third, demand-shift variables are transferred into baseline forecasts. Consequently we need to make judgements about their realism and relevance for the future evolution of the economy.

In making a detailed (and perhaps laborious) analysis of Table 2.4, we are working out what needs to be done in step 15 to improve the realism of the demand-shift results. As it turns out, step 15 is the last step that we are able to undertake for this project, although it will be clear that further steps would be possible.

Our analysis of Table 2.4 is organized into two parts. We start with the 31 commodities for which we have introduced quantity observations in this step, those in the set COM31_OBS. Then we consider the other 26 commodities where we continue to rely only on value data.

Table 2.4. Percentage movements between 2004 and 2014 in world prices, quantities, values and demand shifts for GTAP commodities: step 13 (before the introduction of commodity quantity data) compared with step 14 (after the initial introduction of these data)

			Step 13				Step 14			
			price (1)	quantity (2)	value (3)	demand sh (4)	price (5)	quantity (6)	value (7)	demand sh (8)
	Com	Description	pworld	qworld	v_wldout	wldout_sh	pworld	qworld	v_wldout	wldout_sh
1	pdr	Paddy rice	76.37	36.66	140.68	-41.81	97.09	22.25	140.68	-6.79
2	wht	Wheat	60.01	50.82	140.94	-1.90	110.01	14.82	140.94	-21.48
3	gro	Other grains	69.32	72.91	192.06	14.26	123.19	31.09	192.06	-7.70
4	v_f	Vegetables &fruit	70.32	44.72	146.09	-7.55	95.52	26.02	146.09	-18.09
5	osd	Oil seeds	65.87	60.27	165.31	-14.29	72.95	53.70	165.31	-3.26
6	c_b	Cane & beet	65.65	46.06	141.57	-19.24	77.80	36.06	141.57	-1.51
7	pfb	Plant fibres	63.08	40.58	128.93	-27.45	124.08	2.18	128.93	-45.92
8	ocr	Other crops	57.39	-1.85	54.52	-21.81	19.49	29.36	54.52	1.94
9	ctl	Cattle	56.48	33.01	107.91	-18.48	89.36	9.85	107.91	-16.23
10	oap	Other animal prods	61.19	32.43	113.23	-26.92	85.93	14.76	113.23	-27.39
11	rmk	Raw milk	87.21	-3.28	81.14	-39.44	43.71	26.13	81.14	-11.56
12	wol	Wool	51.97	47.63	124.06	-25.42	124.22	-0.07	124.06	-47.31
13	frs	Forestry	19.92	68.09	101.43	5.25	87.37	7.54	101.43	-29.41
14	fsh	Fishing	52.97	79.37	173.84	15.85	124.53	22.12	173.84	-15.57
15	coa	Coal	100.00	78.33	255.43	10.42	167.05	33.40	255.43	-11.40
16	oil	Oil	167.80	9.83	193.87	-35.48	168.15	9.67	193.87	-0.42
17	gas	Gas	167.80	-13.51	131.93	-33.80	82.86	26.98	131.93	6.47
18	omn	Other mining	38.14	120.53	203.96	17.60	35.87	124.20	203.96	18.57
19	cmt	Cattle meat	36.79	56.63	114.03	19.85	91.89	11.60	114.03	-1.17
20	omt	Other meat	34.31	76.53	136.78	35.81	83.65	29.09	136.78	12.41
21	vol	Vegetable oils	46.88	113.83	213.26	37.32	97.58	58.96	213.26	12.42
22	mil	Milk products	32.98	58.43	110.47	19.42	86.74	12.77	110.47	-0.72
23	pcr	Processed rice	16.30	190.08	236.89	75.63	197.85	13.23	236.89	-20.49
24	sgr	Sugar	37.35	88.07	157.89	29.12	112.97	21.23	157.89	-6.97
25	ofd	Other food	49.94	38.81	107.93	13.98	50.98	37.86	107.93	14.88
26	b_t	Bev & tobac prods	40.51	41.01	97.96	14.49	38.88	42.67	97.96	14.35
27	tex	Textiles	32.09	61.67	113.33	-0.35	30.02	64.25	113.33	-0.35
28	wap	Apparel	35.49	84.32	149.34	41.60	32.73	88.13	149.34	42.49
29	lea	Leather	45.83	61.76	135.55	15.23	46.48	61.04	135.55	14.17
30	lum	Lumber	36.86	18.85	62.62	-1.79	36.05	19.58	62.62	-2.77

Observed (data driven) entries are shaded

Table 2.4 continues …

Table 2.4 continued

			Step 13				Step 14			
			price (1)	quantity (2)	value (3)	demand sh (4)	price (5)	quantity (6)	value (7)	demand sh (8)
	Com	Description	pworld	qworld	v_wldout	wldout_sh	pworld	qworld	v_wldout	wldout_sh
31	ppp	Paper & p prods	39.54	21.21	69.08	-3.74	48.63	13.80	69.08	-8.56
32	p_c	Petroleum & coke	69.84	70.29	188.55	19.51	163.29	9.67	188.55	-17.69
33	crp	Chem rubber prods	44.23	50.33	116.58	5.04	43.36	51.25	116.58	5.19
34	nmm	Non-met minerals	44.87	75.09	153.22	23.27	42.63	77.84	153.22	21.64
35	i_s	Iron & steel	45.25	63.71	137.44	5.35	51.37	57.10	137.44	0.17
36	nfm	Non-ferrous metals	53.62	113.23	226.64	28.93	51.14	116.73	226.64	28.12
37	fmp	Fab metal prods	48.63	30.58	93.96	1.96	45.18	33.70	93.96	1.71
38	mvh	Motor vehicles	45.91	27.18	85.45	1.60	33.33	39.19	85.45	5.18
39	otn	Other transp equip	44.69	43.69	107.70	5.12	40.38	48.11	107.70	4.06
40	ele	Electron equip	36.79	46.39	100.08	2.71	33.39	50.13	100.08	2.65
41	ome	Other mach & equip	42.41	33.93	90.60	-3.98	38.81	37.40	90.60	-3.92
42	omf	Other manu	33.92	53.99	106.01	13.71	31.22	57.15	106.01	13.74
43	ely	Electricity	46.99	37.95	102.62	-11.15	51.42	33.94	102.62	-12.10
44	gdt	Gas distribution	28.10	10.99	42.16	-12.88	26.95	12.00	42.16	-11.24
45	wtr	Water	36.20	32.33	80.12	-5.38	31.51	37.05	80.12	-3.12
46	cns	Construction	47.92	31.30	94.07	-11.91	42.63	36.18	94.07	-10.85
47	trd	Trade	37.21	22.40	67.87	-12.45	33.10	26.19	67.87	-10.28
48	otp	Other transport	49.02	24.98	86.12	0.67	47.65	26.13	86.12	0.07
49	wtp	Water transport	40.35	28.30	79.95	-21.29	26.23	42.65	79.95	-7.85
50	atp	Air transport	60.48	7.71	72.85	-10.34	4.69	65.14	72.85	25.17
51	cmn	Communications	26.06	37.20	72.87	-0.89	22.01	41.75	72.87	0.54
52	ofi	Oth financ intermed	30.27	39.02	80.97	2.51	26.18	43.51	80.97	4.16
53	isr	Insurance	40.28	12.24	57.42	-3.82	36.51	15.35	57.42	-3.18
54	obs	Other bus services	41.78	12.55	59.53	-2.23	37.63	15.94	59.53	-1.45
55	ros	Rec & oth services	33.31	20.62	60.74	-12.04	30.31	23.40	60.74	-10.91
56	osg	Other service govt	41.52	21.87	72.39	-11.47	37.59	25.35	72.39	-9.91
57	dwe	Dwellings	-3.07	64.24	59.22	-2.33	-5.84	69.04	59.22	-0.57

Observed (data driven) entries are shaded

2.2.2(a). Step 14 results for the 31 commodities in the set COM31_OBS

Paddy rice (pdr) and Processed rice (pcr)

In step 14, the observed quantity movement for Paddy rice, 22.25 per cent, replaces step 13's projected movement of 36.66 per cent. As a first guess we might think that this should reduce the demand-shift variable: in step 14 there is now less Paddy rice to absorb. However, the demand-shift variable increases (from -41.81 per cent in step 13 to -6.79 per cent in step 14. There are two reasons. First, with reduced quantity, but fixed value (140.68 per cent in both steps), the price of Paddy rice must rise in the transition from step 13 to step 14 (from 76.37 per cent to 97.09 per cent). The rise in price chokes off demand, thus requiring an increased demand shift to accommodate any given quantity increase. The second reason is the decline in the quantity growth for Processed rice (from 190.08 per cent in step 13 to 13.23 per cent in step 14). With about 65 per cent of Paddy rice being sold as an intermediate input to Processed rice, this decline in the output of Processed rice has a major negative impact on the demand for Paddy rice, leading to an increase in the demand-shift required to absorb a given quantity of Paddy rice.

For Processed rice, the movement in the demand-shift variable is sharply reduced (from the projected 75.63 per cent in step 13 to -20.49 per cent in step 14). This is the net outcome of a negative quantity effect and a positive price effect. The introduction of the observed quantity movement, 13.23 per cent, replacing the projected movement, 190.08 per cent, means that less Processed rice must be absorbed requiring a reduction in the demand-shift variable. This is the negative quantity effect on the demand-shift variable. At the same time, the introduction of the observed quantity movement for Processed rice causes the percentage price increase to move from 16.30 per cent to 197.85 per cent. This reduces demand, requiring an increase in the demand-shift variable. This is the positive price effect on the demand shift variable. Because the price elasticity of demand for Processed rice is relatively low, the negative quantity effect dominates.

A problem to which we will return in setting up step 15 is that step 14 shows a misalignment between the prices of Paddy rice and Processed rice. The increase in the price of Processed rice, 197.85 per cent, seems unrealistically large relative to the 97.09 per cent increase in the price of its principal input, Paddy rice. There is also a possible misalignment between the quantity movements, 13.23 per cent for Processed rice and 22.25 per cent for Paddy rice.

Cattle (ctl) and Cattle meat (cmt)

The story for this pair of products is a damped version of the story for the Paddy-rice/Processed-rice pair. The output movements for the farm product, Cattle, and the processed product, Cattle meat, are reduced in the transition from step 13 to step 14.

The reduction in quantity output growth for the processed product is sufficient to cause an increase in the demand-shift variable for the farm product (from -18.48 per cent to -16.23 per cent) despite the need in step 14 to absorb less Cattle than was the case in step 13.

For the processed product, Cattle meat, the reduction in quantity (from 56.63 per cent to 11.60 per cent) generates a reduction in the demand shift variable (from 19.85 per cent to -1.17 per cent). In the determination of the movement between steps 13 and 14 in the demand-shift variable for Cattle meat, the negative quantity effect dominates the positive price effect. This is similar to the case of Processed rice.

Unlike the Paddy-rice/Processed-rice situation, step 14 does not indicate price and quantity misalignments for Cattle/Cattle-meat.

Cane & beet (c_b) and Sugar (sgr); and Oil seeds (osd) and Vegetable oils (vol)

The results in Table 2.4 for these two pairs of commodities follow the same pattern as those for Cattle/Cattle-meat and Paddy-rice/Processed-rice. In the transition from step 13 to step 14 the quantity movements in the farm products (Cane & beet and Oil seeds) and the processed products (Sugar and Vegetable oils) fall; the demand shifts for the farm products rise; and the demand shifts for the processed products fall.

For the Cane-beet/Sugar pair, step 14 shows possible price and quantity misalignments. The price rise for the processed product, Sugar, is large relative to that for the farm product (112.97 per cent compared with 77.80 per cent), while the quantity movement for the processed product is small relative to that of the farm product (21.23 per cent compared with 36.06 per cent). We found no basis for eliminating either of these possible misalignments. The data on quantity movements seemed unambiguous. On prices, we found data that would support a movement for Sugar of anywhere between -35 per cent and +137 per cent, see World Bank (2020).

For the Oil-seeds/Vegetable-oil pair, the quantity movements are quite closely aligned (53.70 per cent and 58.96 per cent). However there is a gap between the price movements (97.58 per cent for the processed product and 72.95 per cent for the farm product). As with Sugar, we found no data suggesting we should close this gap.

Other animal prods (oap) and Other meat (omt)

Again, for this pair of products, the quantity movements are reduced in the transition from step 13 to 14. Consistent with the results for the previous pairs, the demand shift for the processed product, Other meat, falls (from 35.81 per cent to 12.41 per cent). However, unlike the previous pairs, the demand shift for the farm product, Other animal prods, also falls (from -26.92 per cent to -27.39 per cent). The change in the demand shift for Other animal prods in the transition from steps 13 to 14 is the net effect of a negative quantity effect (the need to absorb less Other animal prods) and a positive effect from the contraction in size of the downstream market. The negative effect slightly outweighs the positive effect.

Step14 shows a quantity misalignment for these two products (29.09 per cent for the processed product and 14.76 for the farm product), which we work on in step 15.

Raw milk (rmk) and Milk products (mil)

For this pair of products, the observed quantity growth in world output used in step 14 for the farm product (Raw milk) exceeds the projected growth generated in step 13 (26.13 per cent compared with -3.28 per cent), whereas the observed growth for the processed product (Milk products) is less than the projected growth (12.77 per cent compared with 58.43 per cent). Both these factors contribute to an increase in the demand shift for Raw milk (from -39.44 per cent in step 13 to -11.56 per cent in step 14). The second factor (the growth reduction for Milk products) explains the reduced demand shift for Milk products (from 19.42 per cent to -0.72 per cent).

Step 14 shows considerable misalignment in the price and quantity results for the two products. The price of the farm product increases by 43.71 per cent. For the processed product, the percentage price increase is nearly twice as large, 86.74 per cent. For quantities, the misalignment is in the opposite direction. The percentage quantity increase for the farm product is more than twice that for the processed product (26.13 per cent compared with 12.77 per cent). In simulation 15 we work on reducing these misalignments.

Wheat (wht), Other grains (gro), Vegetables & fruit (v_f) and Fishing (fsh)

In the GTAP database for 2004, each of these commodities has a diverse sales pattern. However, all of them have considerable sales to Other food (ofd). In step 14, Other food has a positive demand shift (14.88 per cent) whereas Wheat, Other grains, Vegetables & fruit and Fishing all have negative demand shifts (-21.48, -7.70, -18.09 and -15.57 per cent). In light of the observed quantity movements for Wheat, Other grains, Vegetables & fruit and Fishing (14.82, 31.09, 26.02 and 22.12 per cent), the simulated quantity movement for Other food (37.86 per cent) seems too high. In planning step 15, we will investigate options for decreasing the tension between the output movement for Other food and the output movements for the farm products that are used as intermediate inputs to Other food.

Plant fibres (pfb) and Wool (wol)

These two commodities are sold predominantly to Textiles (tex). In the transition from step 13 to 14, there is little change in the quantity movement for Textiles which is not in COM31_OBS. At the same time, there are sharp reductions in the quantity movements for Plant fibres (from 40.58 per cent to 2.18 per cent) and Wool (from 47.63 per cent to -0.07 per cent). Thus, we see in step 14 large negative demand shifts for Plant fibres (-45.92 per cent down from -27.45 per cent in step 13) and Wool (-47.31 per cent down from -25.42 per cent in step 13). We interpret these large negative demand shifts for Plant fibres and Wool as being consistent with rapid replacement of natural fibres with synthetics in the manufacture of textiles.

Forestry (frs), Lumber (lum) and Paper & paper prods (ppp)

Forestry is sold predominantly into Lumber and Paper & paper prods. The observed quantity movement for Forestry (7.54 per cent) is well below those for Lumber and Paper & paper prods (19.58 and 13.80 per cent). We interpret this as meaning that there has been forestry-saving technical change in the production of Lumber and Paper & paper prods, consistent with a trend towards recycling. This technical change is reflected in step 14 by a strongly negative demand shift for Forestry (-29.41 per cent).

Lumber is sold predominantly to Construction. The negative demand shift for Lumber (-2.77 per cent) generated in step 14 is consistent with gradual replacement of lumber products in construction by other building materials such as Non-metallic minerals (nmm, e.g. concrete) and Iron & steel (i_s). Both these latter products have positive demand shifts in step 14 (21.64 per cent and 0.17 per cent).

Paper and paper prods includes publishing. The negative demand shift for this product in step 14 (-8.56 per cent) is consistent with the replacement of paper files and paper products, such as newspapers, with electronic products.

Coal (coa), Oil (oil) and Gas (gas)

The introduction in step 14 of observed growth in the output volumes of these energy commodities leads in our historical simulation to seemingly plausible demand shifts: a shift against coal (-11.40 per cent); close to neutrality for oil (a demand shift of -0.42 per cent); and a shift in favor of gas (6.47 per cent). These results can be compared with those in step 13 which showed an unrealistic demand shift in favor of coal (10.42 per cent) and equally unrealistic demand shifts against oil and gas (-35.48 per cent and -33.80 per cent).

As mentioned in subsection 2.2.1, with the exogenization of their quantities in step 14, it was necessary to endogenize the prices of Coal, Oil and Gas. The endogenous outcome for Oil in step 14 (168.15 per cent) is close to the observed price movement used in step 13 (167.80 per cent). For Coal and Gas the endogenous price movements in step 14 (167.05 and 82.85 per cent) are quite different from the price movements imposed exogenously in step 13 (100.00 and 167.80 per cent). However, unlike the price movement for Oil, the Coal and Gas price movements in step 13 were more in the nature of guesses and observations. In step 15 we seek more data on coal and gas price movements.

Petroleum & coke (p_c) and Electricity (ely)

For these final-use energy commodities, step 14 shows plausible negative demand shifts (-17.69 per cent and -12.10 per cent). This is consistent with improved fuel efficiency in cars and improved energy-efficiency in electrical appliances.

Air transport (atp)

Step 14 introduces strong quantity growth for Air transport (65.14 per cent). With the given value increase of 72.85 per cent, the price increase is only 4.69 per cent. Despite the modest price movement, a large demand shift (25.17 per cent) is required to absorb the observed quantity movement.

The price movement seems in tension with the sharp increase in the price of Petroleum & coke (163.29 per cent). However, there was a considerable improvement between 2004 and 2014 in airline fuel efficiency and a fall in the non-fuel costs per passenger, see International Air Transport Association (2019).

Other crops (ocr), Iron & steel (i_s), Motor vehicles (mvh) and Water transport (wtp)

These are the final four commodities for which we have introduced observed quantity movements in step 14. In all four cases the implied demand shifts are relatively small (1.94, 0.17, 5.18 and -7.85 per cent). Thus, these observed quantity movements are broadly compatible with the GTAP model unassisted by product-specific demand shifts.

2.2.2(b). Step 14 results for the 26 commodities outside the set COM31_OBS

The introduction of quantity data for 31 commodities has only minor effects on the results for the other 26 commodities, those for which $c \notin$COM31_OBS. Among these 26 commodities, the largest absolute difference in the price result as we go from step 13 to step 14 is for Construction (cns), a change of 5.29 percentage points (from 47.92 per cent in step 13 to 42.63 per cent in step 14). With values (v_wldout) held constant between the two steps, Construction also shows the largest percentage point change in the quantity of output, a change of 4.88 percentage points (from 31.30 per cent in step 13 to 36.18 per cent in step 14).

The price and quantity changes for the 26 commodities outside COM31_OBS are caused by changes in input costs. As we go from step 13 to step 14, in most regions there is a small decline in the cost of labor and capital inputs, and a sharp increase in the price of some intermediate inputs such as Petroleum & coke (p_c). With the world price level (averaged over all commodities) held constant, the transition from step 13 to step 14 causes a reduction in the average world price of commodities such as Construction that are primary-factor intensive and use comparatively little Petroleum & coke. Because the quantity output differences between steps 13 and 14 for the 26 commodities outside the set COM31_OBS are small, the differences in the results for the demand shift variable (wldout_sh) are also small.

Of the 26 commodities outside the set COM31_OBS, there are twelve in step 14 whose demand shifts have absolute values of more than 10. In setting up step 15, we consider each of these large shifts with a view to deciding whether they are realistic or need revision.

2.3. Step 15: Tidying up price-quantity misalignments and making adjustments to improve the realism of the demand-shift results

In this step we introduce quantity movements for four additional commodities and revise our step-14 quantity estimate for 7 other commodities. These additions/revisions are bolded in column (6) of Table 2.6. For two other commodities we replaced the GTAP data on value movements with new estimates, bolded in column (7). Finally, we adjusted some of the GTAP parameters that determine expenditure elasticities. The effect of the adjustments on expenditure elasticities can be seen by comparing Tables 2.7 and 2.8. None of these changes required a different closure from that used in step 14, just an expansion of the set COM31_OBS to include the four additional commodities for which quantity movements are now introduced.

Our aim with these changes was to reduce unrealistic price and quantity misalignments identified in step 14. At the same time, we continue the review and improve the results for the demand-shift variables.

As with steps 13 and 14, the changes introduced in this step have only minor effects on regional macro variables. This can be seen by comparing the two panels in Table 2.5.

We start the discussion of Table 2.6 by looking at the twelve commodities for which we did not introduce quantity data in step 14 and for which the demand shift in step 14 had absolute magnitude greater than 10. These twelve commodities are: Other mining (omn), Other food (ofd), Beverages & tobacco (b_t), Apparel (wap), Leather (lea), Non-metallic minerals (nmm), Non-ferrous metals (nfm), Other manufacturing (omf), Gas distribution (gdt), Construction (cns), Trade (trd) and Recreation and other services (ros).

2.3.1. Working on the twelve commodities for which we had no quantity-output data and step 14 produced large demand shifts

We start with six consumer goods.

Other food (ofd), Beverages & tobacco (b_t), Apparel (wap), Leather (lea), Other manufacturing (omf, e.g. furniture) and Recreation and other services (ros)

The demand shifts for *Other food, Beverages & tobacco, Apparel, Leather and Other manufacturing* in step 14 are large positives (14.88, 14.35, 42.49, 14.17 and 13.74 per cent). This led us to wonder whether the expenditure elasticities for these commodities in the GTAP

*Table 2.5. **Real exchange rate movements & primary factor technical changes after 14 steps and 15 steps: percentage changes between 2004 and 2014***

	Results **after step 14**				Results **after step 15**			
	Rel price of GDP	Prim-factor tech change			Rel price of GDP	Prim-factor tech change		
		Total	Non-traded	Traded		Total	Non-traded	Traded
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
USA	-11.20	3.43	14.29	-12.88	-11.20	3.16	14.83	-14.19
Canada	6.58	3.79	-1.88	13.99	6.58	3.92	-0.72	12.32
Mexico	0.88	-8.85	-17.96	4.99	0.88	-9.40	-18.03	3.92
China	52.38	61.58	-33.13	521.81	52.38	57.27	-36.17	561.54
Japan	-31.39	-0.47	126.7	-55.73	-31.39	-1.23	124.32	-56.33
SKorea	-6.48	23.97	48.29	2.82	-6.48	22.45	45.85	1.76
India	-0.07	36.93	39.38	34.14	-0.07	31.94	22.18	44.66
France	-11.75	-0.11	23.88	-23.67	-11.75	-0.48	25.21	-25.23
Germany	-11.57	3.70	32.07	-16.35	-11.57	2.98	34.32	-18.54
UK	-15.97	-2.12	33.73	-31.79	-15.97	-2.54	34.77	-33.10
RoEU	-5.64	-4.13	6.65	-15.58	-5.64	-4.64	7.65	-17.40
SaudiArabia	44.60	-11.86	-41.63	17.21	44.60	-10.57	-39.14	16.81
RoW	31.75	15.54	-13.52	73.63	31.75	14.62	-13.80	71.59

database are too low. If their expenditure elasticities were too low, then demand for these commodities would not expand sufficiently in our historical simulation in response to growth in the world economy. This would lead to large demand shifts to explain quantity movements. For *Recreation and other services*, the demand shift is -10.91. Perhaps the expenditure elasticities for this commodity are too high.

As can be seen from Table 2.8, we moved the expenditure elasticities[7] for:

Other food to values between 0.8 and 1.4 (up from 0.6 to 0.9 in Table 2.7);
Beverages & tobacco to values between 0.8 and 1.4 (up from 0.6 to 0.9);
Apparel to values between 1.6 and 2.4 (up from 0.7 to 0.9);
Leather to values between 1.0 and 1.6 (up from 0.7 to 0.9);
Other manufacturing to values between 1.2 and 1.6 (up from 0.7 to 1.1); and
Recreation & other services to values between 0.9 and 1.0 (down from 1.0 to 1.3).

Having read the description in Hertel *et al.* (2016) of the estimation procedures for the consumer demand system in GTAP, we doubt that they would make an econometric objection to the new ranges that we have adopted for the expenditure elasticities for these products, with the possible exception of Apparel. Consistent with our adoption of high expenditure elasticities for Apparel, the GTAP databases for 2004 and 2014 show increases in the Apparel share of private consumption for all regions, particularly fast growing regions such as China and India.

With the new expenditure elasticities, the demand shifts in step 15 for all six commodities are relatively moderate, in the range -10 to +10.

[7] We moved the expenditure elasticities by adjusting the GTAP parameter INCPAR(c,r). This is γ in Hertel and Tsigas (1997, page 50), see also Corong *et al.* (2017, pages 26-29). For c = ofd, b_t, lea and ofm, we multiplied the GTAP INCPARs for 2004 by 2. For c = ros, we multiplied the GTAP INCPARs for 2004 by 0.7. For c = wap, we multiplied the initial INCPARs by 5 for all countries except China and India. For China the multiplying factor was 3.75 and for India the multiplying factor was 3.

Table 2.6. Percentage movements between 2004 and 2014 in world prices, quantities, values and demand shifts for GTAP commodities: step 14 (before the introduction of commodity value data) compared with step 15 (after the initial introduction of these data)

			Step 14				Step 15			
			price (1)	quantity (2)	value (3)	demand sh (4)	price (5)	quantity (6)	value (7)	demand sh (8)
	Com	Description	pworld	qworld	v_wldout	wldout_sh	pworld	qworld	v_wldout	wldout_sh
1	pdr	Paddy rice	97.09	22.25	140.68	-6.79	97.09	22.25	140.68	-10.16
2	wht	Wheat	110.01	14.82	140.94	-21.48	93.74	**24.51***	140.94	-18.92
3	gro	Other grains	123.19	31.09	192.06	-7.70	123.19	31.09	192.06	-8.36
4	v_f	Vegetables &fruit	95.52	26.02	146.09	-18.09	95.52	26.02	146.09	-16.08
5	osd	Oil seeds	72.95	53.70	165.31	-3.26	72.95	53.70	165.31	-3.44
6	c_b	Cane & beet	77.80	36.06	141.57	-1.51	77.80	36.06	141.57	-1.84
7	pfb	Plant fibres	124.08	2.18	128.93	-45.92	124.08	2.18	128.93	-47.14
8	ocr	Other crops	19.49	29.36	54.52	1.94	19.49	**29.36***	54.52	3.26
9	ctl	Cattle	89.36	9.85	107.91	-16.23	82.49	**14.00***	107.91	-12.46
10	oap	Other animal prods	85.93	14.76	113.23	-27.39	65.24	**29.18***	113.23	-13.43
11	rmk	Raw milk	43.71	26.13	81.14	-11.56	46.83	23.44	81.14	-10.32
12	wol	Wool	124.22	-0.07	124.06	-47.31	124.22	-0.07	124.06	-48.58
13	frs	Forestry	87.37	7.54	101.43	-29.41	87.37	7.54	101.43	-29.61
14	fsh	Fishing	124.53	22.12	173.84	-15.57	124.53	22.12	173.84	-15.36
15	coa	Coal	167.05	33.40	255.43	-11.40	32.45	33.40	**76.58***	-10.43
16	oil	Oil	168.15	9.67	193.87	-0.42	168.15	9.67	193.87	-0.56
17	gas	Gas	82.86	26.98	131.93	6.47	82.86	26.98	131.93	7.66
18	omn	Other mining	35.87	124.20	203.96	18.57	101.99	**50.84***	203.96	-9.32
19	cmt	Cattle meat	91.89	11.60	114.03	-1.17	91.89	11.60	114.03	-1.32
20	omt	Other meat	83.65	29.09	136.78	12.41	80.53	**31.33***	136.78	6.71
21	vol	Vegetable oils	97.58	58.96	213.26	12.42	97.58	58.96	213.26	11.55
22	mil	Milk products	86.74	12.77	110.47	-0.72	69.53	**24.26***	110.47	4.42
23	pcr	Processed rice	197.85	13.23	236.89	-20.49	69.59	**22.25***	**107.16***	-11.82
24	sgr	Sugar	112.97	21.23	157.89	-6.97	112.97	21.23	157.89	-7.88
25	ofd	Other food	50.98	37.86	107.93	14.88	50.16	38.61	107.93	8.63
26	b_t	Bev & tobac prods	38.88	42.67	97.96	14.35	38.01	43.57	97.96	7.96
27	tex	Textiles	30.02	64.25	113.33	-0.35	29.60	64.78	113.33	-1.70
28	wap	Apparel	32.73	88.13	149.34	42.49	28.50	94.31	149.34	7.25
29	lea	Leather	46.48	61.04	135.55	14.17	43.87	63.96	135.55	7.34
30	lum	Lumber	36.05	19.58	62.62	-2.77	36.05	19.58	62.62	-4.27

Observed (data driven) entries are shaded. The bold starred entries in columns (6) and (7) are new values used in step 15.

Table 2.6 continues …

Table 2.6 continued

			Step 14				Step 15			
			price (1)	quantity (2)	value (3)	demand sh (4)	price (5)	quantity (6)	value (7)	demand sh (8)
	Com	Description	pworld	qworld	v_wldout	wldout_sh	pworld	qworld	v_wldout	wldout_sh
31	ppp	Paper & p prods	48.63	13.80	69.08	-8.56	48.63	13.80	69.08	-7.95
32	p_c	Petroleum & coke	163.29	9.67	188.55	-17.69	163.29	9.67	188.55	-16.57
33	crp	Chem rubber prods	43.36	51.25	116.58	5.19	45.17	49.37	116.58	4.97
34	nmm	Non-met minerals	42.63	77.84	153.22	21.64	68.16	**50.84***	153.22	3.27
35	i_s	Iron & steel	51.37	57.10	137.44	0.17	51.37	57.10	137.44	0.73
36	nfm	Non-ferrous metals	51.14	116.73	226.64	28.12	117.11	**50.84***	226.64	-0.45
37	fmp	Fab metal prods	45.18	33.70	93.96	1.71	48.27	30.91	93.96	-0.71
38	mvh	Motor vehicles	33.33	39.19	85.45	5.18	33.33	39.19	85.45	5.32
39	otn	Other transp equip	40.38	48.11	107.70	4.06	42.14	46.27	107.70	3.41
40	ele	Electron equip	33.39	50.13	100.08	2.65	34.88	48.48	100.08	2.29
41	ome	Other mach & equip	38.81	37.40	90.60	-3.92	41.20	35.08	90.60	-4.83
42	omf	Other manu	31.22	57.15	106.01	13.74	32.64	55.47	106.01	9.64
43	ely	Electricity	51.42	33.94	102.62	-12.10	51.42	33.94	102.62	-9.18
44	gdt	Gas distribution	26.95	12.00	42.16	-11.24	27.95	11.13	42.16	-10.85
45	wtr	Water	31.51	37.05	80.12	-3.12	32.68	35.84	80.12	-3.67
46	cns	Construction	42.63	36.18	94.07	-10.85	33.53	**45.47***	94.07	-5.00
47	trd	Trade	33.10	26.19	67.87	-10.28	33.87	25.45	67.87	-10.74
48	otp	Other transport	47.65	26.13	86.12	0.07	49.58	24.50	86.12	-0.20
49	wtp	Water transport	26.23	42.65	79.95	-7.85	26.23	42.65	79.95	-5.69
50	atp	Air transport	4.69	65.14	72.85	25.17	4.69	65.14	72.85	25.33
51	cmn	Communications	22.01	41.75	72.87	0.54	22.89	40.74	72.87	0.03
52	ofi	Oth financ intermed	26.18	43.51	80.97	4.16	27.12	42.45	80.97	3.73
53	isr	Insurance	36.51	15.35	57.42	-3.18	38.06	14.05	57.42	-3.92
54	obs	Other bus services	37.63	15.94	59.53	-1.45	39.66	14.26	59.53	-2.41
55	ros	Rec & oth services	30.31	23.40	60.74	-10.91	30.58	23.14	60.74	-9.29
56	osg	Other service govt	37.59	25.35	72.39	-9.91	38.55	24.48	72.39	-10.43
57	dwe	Dwellings	-5.84	69.04	59.22	-0.57	-5.46	68.37	59.22	-1.25

Observed (data driven) entries are shaded. The bold starred entries in columns (6) and (7) are new values used in step 15.

Table 2.7. Expenditure elasticities of demand (EY) in GTAP database for 2004, used in Step 14: Highlighted rows are for commodities in which household demand is more than 30% of world total demand

			1 USA	2 Canada	3 Mexico	4 China	5 Japan	6 SKorea	7 India	8 France	9 Germany	10 UK	11 RoEU	12 Saudi Arabia	13 RoW
1	pdr	Paddy rice	0.008	0.020	0.198	0.685	0.020	0.085	0.695	0.021	0.019	0.011	0.066	0.284	0.769
2	wht	Wheat	0.008	0.020	0.198	0.685	0.020	0.085	0.695	0.021	0.019	0.011	0.074	0.284	0.531
3	gro	Other grains	0.008	0.020	0.198	0.685	0.020	0.085	0.695	0.021	0.019	0.011	0.194	0.284	0.684
4	v_f	Veg & fruit	0.008	0.020	0.198	0.685	0.020	0.085	0.695	0.021	0.019	0.011	0.065	0.284	0.543
5	osd	Oil seeds	0.008	0.020	0.198	0.685	0.020	0.085	0.695	0.021	0.019	0.011	0.057	0.284	0.712
6	c_b	Cane & beet	0.008	0.020	0.198	0.685	0.020	0.085	0.695	0.021	0.019	0.011	0.057	0.284	0.481
7	pfb	Plant fibres	0.909	0.871	0.724	0.852	0.892	0.771	0.918	0.886	0.887	0.903	0.836	0.719	0.817
8	ocr	Other crops	0.008	0.020	0.198	0.685	0.020	0.085	0.695	0.021	0.019	0.011	0.083	0.284	0.550
9	ctl	Cattle	0.899	0.857	0.701	0.845	0.879	0.749	0.914	0.872	0.874	0.892	0.750	0.697	0.899
10	oap	Oth anim prods	0.899	0.857	0.701	0.845	0.879	0.749	0.914	0.872	0.874	0.892	0.778	0.697	0.823
11	rmk	Raw milk	0.899	0.857	0.701	0.845	0.879	0.749	0.914	0.872	0.874	0.892	0.789	0.697	0.835
12	wol	Wool	0.909	0.871	0.724	0.852	0.892	0.771	0.918	0.886	0.887	0.903	0.876	0.719	0.826
13	frs	Forestry	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.048	1.098	0.907
14	fsh	Fishing	0.899	0.857	0.701	0.845	0.879	0.749	0.914	0.872	0.874	0.892	0.849	0.697	0.846
15	coa	Coal	0.990	0.992	0.990	0.898	1.002	1.001	0.850	1.003	1.001	0.995	0.981	0.997	0.993
16	oil	Oil	0.982	0.980	0.960	0.965	0.992	0.977	1.004	0.992	0.990	0.986	0.993	0.965	1.066
17	gas	Gas	0.990	0.992	0.990	0.898	1.002	1.001	0.850	1.003	1.001	0.995	1.005	0.997	0.966
18	omn	Other mining	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.039	1.098	0.996
19	cmt	Cattle meat	0.899	0.857	0.701	0.845	0.879	0.749	0.914	0.872	0.874	0.892	0.852	0.697	0.768
20	omt	Other meat	0.899	0.857	0.701	0.845	0.879	0.749	0.914	0.872	0.874	0.892	0.818	0.697	0.775
21	vol	Vegetable oils	0.866	0.810	0.633	0.793	0.836	0.678	0.805	0.828	0.830	0.855	0.781	0.631	0.738
22	mil	Milk products	0.899	0.857	0.701	0.845	0.879	0.749	0.914	0.872	0.874	0.892	0.837	0.697	0.773
23	pcr	Processed rice	0.008	0.020	0.198	0.685	0.020	0.085	0.695	0.021	0.019	0.011	0.059	0.284	0.615
24	sgr	Sugar	0.866	0.810	0.633	0.793	0.836	0.678	0.805	0.828	0.830	0.855	0.762	0.631	0.752
25	ofd	Other food	0.866	0.810	0.633	0.793	0.836	0.678	0.805	0.828	0.830	0.855	0.787	0.631	0.719
26	b_t	Bev & tobac prd	0.866	0.810	0.633	0.793	0.836	0.678	0.805	0.828	0.830	0.855	0.783	0.631	0.725
27	tex	Textiles	0.909	0.871	0.724	0.852	0.892	0.771	0.918	0.886	0.887	0.903	0.855	0.719	0.826
28	wap	Apparel	0.909	0.871	0.724	0.852	0.892	0.771	0.918	0.886	0.887	0.903	0.864	0.719	0.794
29	lea	Leather	0.909	0.871	0.724	0.852	0.892	0.771	0.918	0.886	0.887	0.903	0.856	0.719	0.793
30	lum	Lumber	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.042	1.098	1.037

Table 2.7 continues …

Table 2.7 continued

		R001	1 USA	2 Canada	3 Mexico	4 China	5 Japan	6 SKorea	7 India	8 France	9 Germany	10 UK	11 RoEU	12 Saudi Arabia	13 RoW
31	ppp	Paper & p prods	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.040	1.098	1.036
32	p_c	Petroleum & coke	0.982	0.980	0.960	0.965	0.992	0.977	1.004	0.992	0.990	0.986	0.987	0.965	0.970
33	crp	Chem rubber prods	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.043	1.098	1.032
34	nmm	Non-met minerals	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.045	1.098	1.013
35	i_s	Iron & steel	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.054	1.098	1.008
36	nfm	Non-ferrous metals	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.059	1.098	1.034
37	fmp	Fab metal prods	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.040	1.098	1.034
38	mvh	Motor vehicles	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.040	1.098	1.038
39	otn	Other transp equip	0.982	0.980	0.960	0.965	0.992	0.977	1.004	0.992	0.990	0.986	0.992	0.965	0.987
40	ele	Electron equip	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.039	1.098	1.038
41	ome	Other mach & equip	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.041	1.098	1.039
42	omf	Other manu	1.008	1.020	1.078	0.835	1.028	1.067	0.677	1.030	1.028	1.015	1.041	1.098	1.044
43	ely	Electricity	0.990	0.992	0.990	0.898	1.002	1.001	0.850	1.003	1.001	0.995	1.000	0.997	0.977
44	gdt	Gas distribution	0.990	0.992	0.990	0.898	1.002	1.001	0.850	1.003	1.001	0.995	1.002	0.997	0.968
45	wtr	Water	0.990	0.992	0.990	0.898	1.002	1.001	0.850	1.003	1.001	0.995	1.003	0.997	0.982
46	cns	Construction	0.990	0.992	0.990	0.898	1.002	1.001	0.850	1.003	1.001	0.995	0.999	0.997	0.988
47	trd	Trade	1.021	1.042	1.166	1.314	1.047	1.124	1.332	1.051	1.048	1.031	1.067	1.220	1.157
48	otp	Other transport	0.982	0.980	0.960	0.965	0.992	0.977	1.004	0.992	0.990	0.986	0.988	0.965	0.973
49	wtp	Water transport	0.982	0.980	0.960	0.965	0.992	0.977	1.004	0.992	0.990	0.986	0.993	0.965	0.982
50	atp	Air transport	0.982	0.980	0.960	0.965	0.992	0.977	1.004	0.992	0.990	0.986	0.989	0.965	0.972
51	cmn	Communications	0.982	0.980	0.960	0.965	0.992	0.977	1.004	0.992	0.990	0.986	0.987	0.965	0.970
52	ofi	Oth financ intermed	1.025	1.049	1.194	1.418	1.053	1.142	1.439	1.057	1.055	1.036	1.080	1.258	1.187
53	isr	Insurance	0.990	0.992	0.990	0.898	1.002	1.001	0.850	1.003	1.001	0.995	1.004	0.997	0.984
54	obs	Other bus services	1.025	1.049	1.194	1.418	1.053	1.142	1.439	1.057	1.055	1.036	1.080	1.258	1.204
55	ros	Rec & oth services	1.021	1.041	1.162	1.259	1.046	1.121	1.231	1.050	1.047	1.030	1.065	1.215	1.166
56	osg	Other service govt	1.021	1.041	1.162	1.259	1.046	1.121	1.231	1.050	1.047	1.030	1.067	1.215	1.142
57	dwe	Dwellings	1.021	1.041	1.162	1.259	1.046	1.121	1.231	1.050	1.047	1.030	1.065	1.215	1.137

Table 2.8. Expenditure elasticities of demand (EY) for 2004, used in Step 15: Highlighted rows are for commodities in which household demand is more than 30% of world total demand

			1 USA	2 Canada	3 Mexico	4 China	5 Japan	6 SKorea	7 India	8 France	9 Germany	10 UK	11 RoEU	12 Saudi Arabia	13 RoW
1	pdr	Paddy rice	0.003	0.010	0.176	0.421	0.012	0.068	0.422	0.012	0.009	0.005	0.052	0.259	0.433
2	wht	Wheat	0.003	0.010	0.176	0.421	0.012	0.068	0.422	0.012	0.009	0.005	0.060	0.259	0.320
3	gro	Other grains	0.003	0.010	0.176	0.421	0.012	0.068	0.422	0.012	0.009	0.005	0.175	0.259	0.391
4	v_f	Veg & fruit	0.003	0.010	0.176	0.421	0.012	0.068	0.422	0.012	0.009	0.005	0.052	0.259	0.319
5	osd	Oil seeds	0.003	0.010	0.176	0.421	0.012	0.068	0.422	0.012	0.009	0.005	0.044	0.259	0.401
6	c_b	Cane & beet	0.003	0.010	0.176	0.421	0.012	0.068	0.422	0.012	0.009	0.005	0.045	0.259	0.287
7	pfb	Plant fibres	0.895	0.843	0.682	0.809	0.875	0.735	0.921	0.863	0.857	0.885	0.802	0.676	0.761
8	ocr	Other crops	0.003	0.010	0.176	0.421	0.012	0.068	0.422	0.012	0.009	0.005	0.069	0.259	0.329
9	ctl	Cattle	0.764	0.680	0.404	0.377	0.723	0.519	0.374	0.706	0.701	0.740	0.476	0.452	0.394
10	oap	Oth anim prods	0.764	0.680	0.404	0.377	0.723	0.519	0.374	0.706	0.701	0.740	0.531	0.452	0.392
11	rmk	Raw milk	0.764	0.680	0.404	0.377	0.723	0.519	0.374	0.706	0.701	0.740	0.541	0.452	0.377
12	wol	Wool	0.895	0.843	0.682	0.809	0.875	0.735	0.921	0.863	0.857	0.885	0.846	0.676	0.767
13	frs	Forestry	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.009	1.038	0.843
14	fsh	Fishing	0.886	0.830	0.660	0.802	0.862	0.713	0.917	0.849	0.844	0.874	0.818	0.655	0.786
15	coa	Coal	0.976	0.962	0.938	0.853	0.984	0.958	0.853	0.977	0.969	0.975	0.935	0.943	0.927
16	oil	Oil	0.968	0.950	0.908	0.918	0.974	0.934	1.007	0.967	0.958	0.967	0.960	0.912	0.985
17	gas	Gas	0.976	0.962	0.938	0.853	0.984	0.958	0.853	0.977	0.969	0.975	0.973	0.943	0.898
18	omn	Other mining	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.007	1.038	0.929
19	cmt	Cattle meat	0.886	0.830	0.660	0.802	0.862	0.713	0.917	0.849	0.844	0.874	0.823	0.655	0.719
20	omt	Other meat	1.048	1.030	1.001	1.370	1.047	0.973	1.641	1.041	1.035	1.054	1.035	0.927	1.134
21	vol	Vegetable oils	0.853	0.784	0.593	0.753	0.819	0.645	0.808	0.805	0.801	0.838	0.751	0.592	0.686
22	mil	Milk products	0.886	0.830	0.660	0.802	0.862	0.713	0.917	0.849	0.844	0.874	0.807	0.655	0.726
23	pcr	Processed rice	0.003	0.010	0.176	0.421	0.012	0.068	0.422	0.012	0.009	0.005	0.046	0.259	0.358
24	sgr	Sugar	0.853	0.784	0.593	0.753	0.819	0.645	0.808	0.805	0.801	0.838	0.731	0.592	0.697
25	ofd	Other food	1.010	0.975	0.905	1.284	0.997	0.880	1.444	0.988	0.983	1.010	0.973	0.838	1.045
26	b_t	Bev & tobac prd	1.010	0.975	0.905	1.284	0.997	0.880	1.444	0.988	0.983	1.010	0.965	0.838	1.056
27	tex	Textiles	0.895	0.843	0.682	0.809	0.875	0.735	0.921	0.863	0.857	0.885	0.825	0.676	0.773
28	wap	Apparel	1.554	1.658	2.087	2.383	1.631	1.812	2.371	1.641	1.634	1.613	1.712	1.799	2.301
29	lea	Leather	1.060	1.047	1.035	1.380	1.063	1.004	1.647	1.057	1.052	1.067	1.061	0.958	1.141
30	lum	Lumber	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.007	1.038	0.979

Table 2.8 continues …

Table 2.8 continued

		R001	1 USA	2 Canada	3 Mexico	4 China	5 Japan	6 SKorea	7 India	8 France	9 Germany	10 UK	11 RoEU	12 Saudi Arabia	13 RoW
31	ppp	Paper & p prods	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.004	1.038	0.978
32	p_c	Petroleum & coke	0.968	0.950	0.908	0.918	0.974	0.934	1.007	0.967	0.958	0.967	0.954	0.912	0.912
33	crp	Chem rubber prods	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.006	1.038	0.971
34	nmm	Non-met minerals	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.006	1.038	0.956
35	i_s	Iron & steel	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.012	1.038	0.957
36	nfm	Non-ferrous metals	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.016	1.038	0.990
37	fmp	Fab metal prods	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.007	1.038	0.978
38	mvh	Motor vehicles	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.007	1.038	0.982
39	otn	Other transp equip	0.968	0.950	0.908	0.918	0.974	0.934	1.007	0.967	0.958	0.967	0.960	0.912	0.928
40	ele	Electron equip	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.007	1.038	0.984
41	ome	Other mach & equip	0.993	0.991	1.021	0.793	1.008	1.022	0.679	1.004	0.994	0.996	1.007	1.038	0.984
42	omf	Other manu	1.175	1.233	1.559	1.354	1.227	1.407	1.212	1.234	1.222	1.202	1.289	1.500	1.446
43	ely	Electricity	0.976	0.962	0.938	0.853	0.984	0.958	0.853	0.977	0.969	0.975	0.965	0.943	0.916
44	gdt	Gas distribution	0.976	0.962	0.938	0.853	0.984	0.958	0.853	0.977	0.969	0.975	0.969	0.943	0.902
45	wtr	Water	0.976	0.962	0.938	0.853	0.984	0.958	0.853	0.977	0.969	0.975	0.969	0.943	0.929
46	cns	Construction	0.976	0.962	0.938	0.853	0.984	0.958	0.853	0.977	0.969	0.975	0.961	0.943	0.937
47	trd	Trade	1.007	1.011	1.108	1.246	1.029	1.075	1.339	1.025	1.016	1.010	1.032	1.157	1.094
48	otp	Other transport	0.968	0.950	0.908	0.918	0.974	0.934	1.007	0.967	0.958	0.967	0.955	0.912	0.916
49	wtp	Water transport	0.968	0.950	0.908	0.918	0.974	0.934	1.007	0.967	0.958	0.967	0.960	0.912	0.926
50	atp	Air transport	0.968	0.950	0.908	0.918	0.974	0.934	1.007	0.967	0.958	0.967	0.957	0.912	0.918
51	cmn	Communications	0.968	0.950	0.908	0.918	0.974	0.934	1.007	0.967	0.958	0.967	0.954	0.912	0.917
52	ofi	Oth financ intermed	1.011	1.018	1.135	1.352	1.034	1.095	1.441	1.031	1.021	1.015	1.044	1.194	1.127
53	isr	Insurance	0.976	0.962	0.938	0.853	0.984	0.958	0.853	0.977	0.969	0.975	0.972	0.943	0.935
54	obs	Other bus services	1.011	1.018	1.135	1.352	1.034	1.095	1.441	1.031	1.021	1.015	1.044	1.194	1.141
55	ros	Rec & oth services	0.943	0.933	0.921	0.935	0.957	0.946	0.942	0.952	0.943	0.946	0.944	0.998	0.931
56	osg	Other service govt	1.006	1.009	1.102	1.197	1.027	1.074	1.239	1.023	1.014	1.010	1.032	1.151	1.082
57	dwe	Dwellings	1.006	1.009	1.102	1.197	1.027	1.074	1.239	1.023	1.014	1.010	1.029	1.151	1.079

Next we consider three mineral-based products.

Other mining (omn), Non metallic mineral products (nmm) and Non ferrous metals (nfm)

The demand shift for Other mining in step 14 is 18.57 and the percentage price increase is 35.87. We suspect that these results mean that step 14 is overestimating the percentage increase in quantity (124.2 per cent).

The products included in Other mining are a wide variety of metals and gems plus building material such as stone, gravel and sand. We obtained data from the U.S. Geographical Survey for output movements in the main metals, see Table 2.9. However, we did not find usable data for the building materials. On the basis of Table 2.9 we used 50.84 per cent as the quantity growth for Other mining. We note that the quantity growth in world investment was 45.47 per cent. So we suspect that if we had been able to obtain an estimate for building materials, it would not have made much difference in our quantity growth estimate for the Other mining sector.

Table 2.9 implies a price increase of 106 per cent. In our step 15 simulation the implied price increase for Other mining turns out to be about 102 per cent, in close agreement with the estimate in Table 2.9 for the main metals.

In step 14 the quantity output increases for Non metallic mineral products and Non ferrous metals are 77.84 and 116.73 per cent. These output increases are out of line with the 50.84 per cent that we are now assuming for Other mining, which is the principal raw material for both Non metallic mineral products and Non ferrous metals. We decided to fix the quantity increases for Non metallic mineral products and Non ferrous metals at the Other mining number, 50.84 per cent.

With these estimates of quantity output growth, the demand shifts in step 15 for the three commodities fall in the range -10 to +10.

Construction (cns)

The demand shift for this commodity in step 14 is -10.85. We brought this demand shift above -10 by setting its world quantity output growth in line with investment, 45.47 per cent.

Gas distribution (gdt) and Trade (trd)

The demand shifts for these commodities in step 14 are -11.24 and -10.28 per cent. Gas distribution consists mainly of a product often made of coal and known as Town gas. We decided to accept that between 2004 and 2014 there was a sizable demand shift against Gas distribution (-10.85 per cent in step 15), with a shift towards natural Gas (gas, 7.66 per cent in step 15).

Trade consists mainly of wholesale trade and retail trade. Again, we decided to accept a sizeable negative demand shift (-10.74 per cent in step 15), consistent with the movement towards online shopping and efficiency improvements is warehousing and storage.

Table 2.9. Data from the U.S. Geographical Survey on world output and prices of mineral products

	2004			2014				
	Quantity	Price	Value	Quantity	Price	Value	Quantity	Price
	Billion tons	$US per ton	$USb	Billion tons	$US per ton	$USb	%Δ	%Δ
Iron ore	1.360	31.44	42.76	2.290	131.52	301.18	68.38	318.32
Copper	0.0147	2946.68	43.32	0.0184	6997.10	128.75	25.17	137.46
Bauxite	0.160	30.80	4.93	0.259	37.79	9.79	61.88	22.69
Alumina	0.060	323.03	19.38	0.107	441.00	47.19	78.33	36.52
Uranium	$0.0403*10^{-3}$	45,000	1.81	$0.0560*10^{-3}$	110,000	6.16	38.96	144.44
Gold	$2.44*10^{-6}$	$13.2*10^{6}$	32.21	$3.02*10^{-6}$	$40.86*10^{6}$	123.39	23.77	209.55
Nickel	0.0014	13,823	19.35	0.00235	16,865	39.63	67.86	22.01
Silver	$0.0198*10^{-3}$	$0.215*10^{6}$	4.259	$0.027*10^{-3}$	$0.613*10^{6}$	16.55	36.36	185.12
Total			298.519			928.48	50.84[(a)]	106.19[(b)]

Source: Metals and minerals yearbook produced by the U.S. Geographical survey, available at https://www.usgs.gov/centers/nmic/minerals-yearbook-metals-and-minerals

(a) Value-weighted average of quantity movements for individual products.

(b) Backed out to be consistent with total value and quantity movements.

2.3.2. Adjustments for other commodities that have problematic results in step 14

Processed rice (pcr)

As mentioned in the subsection 2.1.2(a), we were concerned with the unrealistic price result in step 14 for Processed rice (an increase of 197.85 per cent). From Indexmundi.org, who used U.S. Department of Agriculture and World Bank data, we deduced that a more reasonable estimate of the price increase between 2004 and 2014 for Processed rice is 69.43 per cent. At this stage we have a problem: we have observed the quantity increase (13.23 per cent), the price increase (69.43 per cent) and the value increase (236.89 per cent).

We decided to abandon the GTAP-based value increase for Processed rice which seems quite out of line with the GTAP-based value increase for Paddy rice. We also decided to bring the quantity movement for Processed rice into line with that for Paddy rice (an adjustment from 13.23 per cent to 22.25 per cent). With the adjusted quantity and the observed price, we reset the GTAP value increase for Processed rice at 107.16 per cent [= 100*(1.6943*1.2225 -1)].

After these changes, we ran a preliminary version of step 15 which gave a demand shift for Processed rice of -17.33 per cent. This large negative demand shift led us to wonder whether the expenditure elasticities of demand for Processed rice were too high. In Table 2.7, these elasticities are very low for all regions except China, India and ROW. For these three regions the expenditure elasticities in Table 2.7 are 0.685, 0.695 and 0.615. We reduced these three elasticities to values around 0.4, see Table 2.8.[8] These values are considerably higher than those for Processed rice in all other regions. With the revised expenditure elasticities, the

[8] This was done by adjusting INCPAR(c,r) for c = Processed rice and r = China, India and ROW (see previous footnote).

demand-shift for Processed rice in the final version of step 15 is a more moderate -11.82 per cent (see Table 2.6).

Paddy rice (pdr), Wheat (wht), Other grains (gro), Vegetables & fruit (v_f), Oil seeds (osd), Cane and beet (c_b) and Other crops (ocr)

In step 14, the demand shifts are negative for all of these commodities except Other crops which has a small positive demand shift, 1.94 per cent. For any given single-country region we see from Table 2.7 that the GTAP expenditure elasticities have the same value for all six commodities: very low for all regions except for China, India and ROW. We reduced the elasticities for the six commodities in these three regions (compare their values in Tables 2.7 and 2.8) with the aim of moving the demand shifts towards zero.[9] In a preliminary version of step 15, as expected, the demand-shift variables for the six products moved upwards. However, the movements were not large and the demand-shift values remained negative for five of the six products.

For four of the six products, the demand shifts in the preliminary version of step 15 were moderate. However for Wheat and Vegetables & fruit the demand shifts remained large negatives. We revisited our quantity output growth numbers for both of these products. For Vegetables & fruit we found no basis for revision. Consequently we accept that there was a taste change against Vegetables & fruit by households (the main user of the product) and by Other food (also a substantial user of the product). In the final version of step 15, the demand shift for Vegetables & fruit is -16.08 per cent.

For Wheat, we made revisions as described in the next paragraph.

Wheat (wht)

Step 14 generated a demand shift of -21.48 per cent for Wheat. The source we used for the observed quantity growth is unambiguous for production (FAO, see appendix 1): there is no basis for rejecting 14.82 per cent. However, we noted that 2004 was a high year for production and 2003 was a low year. We suspect that there was stock rundown in 2003 and replacement in 2004. Ideally we should model stock movements. As an alternative, we decided to replace output growth for wheat with consumption growth. Using data from Rabo Research (2017) we estimated consumption growth for Wheat as 24.51 per cent.

With the revised quantity growth rate of 24.51 per cent, the demand shifter for Wheat moves in the expected direction but remains strongly negative, -18.90 per cent in the final version of step 15. The main customer for Wheat is Other food, with quantity growth in step 15 of 38.61 per cent. We interpret the shift against Wheat as a taste change against wheat-based products in the Other food category.

Raw milk (rmk) and Milk products (Mil)

As noted in the discussion of these two products in subsection 2.1.2(a), our data on quantity output growth indicate a considerable misalignment (26.13 per cent for Raw milk and only 12.77 per cent for Milk products). We revisited the data and reassigned skimmed, condensed and powdered milk products to Raw milk and away from Milk products. This gave revised quantity growth estimates for Raw milk of 23.44 per cent and for Milk products of 24.26 per cent, thus resolving the quantity misalignment problem. It also reduced the price misalignment. The price for Raw milk in step 15 increases by 46.83 per cent (up from 43.71

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[9] Again, we adjusted INCPAR.

per cent in step 14) and the price for Milk products increases by 69.53 per cent (down from 86.74 per cent in step 14).

However there was still the problem of a large demand shift against Raw milk (-11.56 per cent in step 14), which was exacerbated by the adjustments to the quantity growth rates. In Table 2.7 we see that the expenditure elasticties for Raw milk are in the range 0.7 to 0.9. We suspect that these elasticities are too high. We lowered them to the range 0.4 to 0.8, see Table 2.8. This moved the demand-shift variable for Raw milk back to -10.32 in the final version of step 15 (see Table 2.6).

Cattle (ctl)

Step 14 generated a demand shift of -16.23 per cent for Cattle. Why is a large negative demand shift required for Cattle even though its observed quantity output increase (9.85 per cent) is closely in line with the observed output increase for its main customer, Cattle meat (11.60 per cent)? Looking at the GTAP data we found that about 35 per cent of worldwide Cattle sales go to customers outside Cattle meat. These customers include households and Other meat. Quantity growth for these other customers is higher (averaging about 30 per cent) than the observed quantity growth adopted for Cattle (9.85 per cent). This generates the need for a large negative demand shift.

The growth number we used for Cattle reflects heads of cattle and various other animals (e.g. sheep) that are included in the Cattle category. This could be an inadequate measure of Cattle output if weight per head changed. We investigated this possibility and found that meat per head of cattle increased by between 4 and 5 per cent in the decade from 2004 to 2014, see Ritchie and Roser (2017, 2019). On this basis we adjusted Cattle quantity growth up from 9.85 per cent to 14.00 per cent, which moved the Cattle demand shift in a preliminary version of step 15 to -13.74 per cent. We moved this shift further up towards zero (to -12.46 per cent in the final version of step 15) by adjusting the expenditure elasticities for Cattle. In the original GTAP data these elasticities were in the range 0.7 to 0.9 (see Table 2.7). After the adjustment here they were in the range 0.4 to 0.8 (see Table 2.8).

Other animal prods (oap) and Other meat (omt)

Step 14 generated demand shifts for these two products of -27.39 and 12.41 per cent. We investigated whether the observed quantity growth used for Other animal prods in step 14 (14.76 per cent) is too low, and/or whether the observed quantity growth used for Other meat (29.09 per cent) is too high.

The main constituents of Other animal prods are pigs and poultry. In step 14 our growth estimate for Other animal prods was based on stocks. We combined the numbers of these animals, giving a weight of 50 to pigs and 1 to chickens & turkeys. We now found data [see see Ritchie and Roser (2017, 2019)] on numbers of slaughtered pigs and poultry and tonnes of meat produced. These data did not indicate a significant change in meat per animal between 2004 and 2014. However, they did indicate that significant revision was required to our step 14 estimate of quantity growth for Other animal products. Using the slaughter numbers from Ritchie and Rosser (again with weights of 50 for Pigs and 1 for poultry) we obtained a revised estimate for quantity growth for Other animal prods of 29.18 per cent. We used the data from Ritchie and Rosser on production of tonnes of output to make a minor revision to the quantity growth for Other meat (31.33 per cent in step 15, up from 29.09 per cent in step 14).

As a final revision we adjusted the expenditure elasticities for the two products. In the original GTAP data, the elasticities for both Other animal prods and Other meat are in the range 0.7 to 0.9 (see Table 2.7). The revised values are in the range 0.4 to 0.8 for Other animal prods and 0.9 to 1.6 for Other meat (see Table 2.8).

After these revisions, the demand shifts for the two products move to moderate values, -13.43 for Other animal prods and 6.71 for Other meat.

3. From an historical to a baseline simulation

As described in section 1, one of the applications of historical simulations is to provide information to baseline simulations. The usual role of a baseline simulation is to give a business-as-usual picture of the future evolution of the economy. This picture is often of interest in itself, while at the same time providing a benchmark against which the effects of policies can be assessed.

So that a baseline can deliver a worthwhile picture at the industry level, we need to introduce trends in technologies and consumer preferences. These can be obtained from an historical simulation. In this section, we show how trends from the historical simulation described in section 2 can be used in a baseline simulation with the GTAP-RD model. GTAP-RD is the latest dynamic version of GTAP, see Aguiar *et al.* (2019). It replaces the earlier dynamic model, GTAP-Dyn, created by Ianchovichina and McDougall (2000) and Ianchovichina and Walmsley (2012).

The version of GTAP we used in section 2 is identical in theoretical structure to GTAP-RD in all aspects relevant to this project[10]. As documented in subsection 3.1.2, we adjust some of the standard parameter settings in GTAP-RD to bring them into line with those in the historical simulation. It is important that technology and preference trends used in a baseline simulation come from a model that is compatible in theoretic structure and parameter settings with the baseline model. Trends brought in from a non-compatible model may be quite misleading. For example, an observed reduction in the use of labor per unit of output may, in a Leontief model, look like a pure change in technology. In GTAP, with substitution allowed between primary factors, the same reduction in the use of labor per unit of output may look like a price-induced substitution effect.

The GTAP team is developing a baseline for GTAP and gave us advanced access, see Aguiar *et al.* (2020). Their baseline relies on projections of macro variables: GDP, population and labor supply. Starting from the end-point of our historical simulation, 2014, we create a GTAP-RD baseline for 2014 to 2017 using macro trends provided by the GTAP team. To this baseline we then add trends in technologies and preferences derived from our 2004-2014 historical simulation. Our aim is to see what difference these trends make to baseline growth projections for outputs by commodity and region.

The historical simulation in section 2 produced trends in several technology and preference variables. As described in our preliminary report[11] these included: productivity in traded and non-traded industries in each region; twists in import-domestic preferences at the macro level in each region; and preference twists by importing regions between alternative supplying regions for a selection of manufactured products. In this report we have focused on wldout_sh(c), for all commodities c. This variable imparts an equal percentage change to the

[10] The coding in our version of GTAP differs from that in GTAP-RD and we allow for industry-specific capital and lagged wage adjustments, features not available in GTAP-RD, see Dixon *et al.* (2019). However, these additional features are not used in the current application.

[11] See Dixon and Rimmer, (2020, May 30)

quantity of commodity c demanded by intermediate and final users across regions. While we can use trends in a variety of technology/preference variables in a baseline simulation, here we chose to use only trends in wldout_sh(c) for all c. The historical results for this variable are the best-understood among our technology/preference trends, and provide the most complete coverage at the industry/commodity level. We judge that these trends are more likely to persist into the future than those in our other technology/preference variables and that they are likely to be the most influential in forming the industry dimension of a baseline. We hope to test these judgements in future research.

In subsection 3.1 we deal with technical matters that can be skipped by readers who are not interested in the GEMPACK details of our two baseline GTAP-RD simulations: with and without the wldout_sh trends. In subsection 3.2 we give results on the effects of introducing the wldout_sh trends.

3.1. Changes to the GTAP-RD code to facilitate the use of wldout_sh trends in baseline projections

3.1.1. Additions

Our additions to the GTAP-RD code occur in 8 blocks marked with opening and closing tags: !P&M210820*** ! and ! ***P&M210820! . Where required, we provide a brief explanation for each block.

Block 1: Mapping from 65 commodities to 57

The standard version of GTAP-RD for 2014 recognizes 65 commodities. This is a recent change from the original 57 commodities. Our trends for wldout_sh were estimated in a model at the 57 level. The code in this block introduces a mapping from 65 to 57 and applies it to work out a 65 commodity version of the parameter INCPAR.

```
!P&M210820*** !
SET TRAD_COMM     # 57 coms  #
   read elements from file GTAPPARM header "H2";
Mapping MP57 from COMM to TRAD_COMM;
Read (by_elements) MP57 from file GTAPPARM  header "MP57";
Coefficient (Parameter)(All,i,TRAD_COMM)(All,r,REG) IN57(i,r) # INCPAR at the 57 level from historical sim #;
Read IN57 from file GTAPPARM header "IN57";
Formula (Initial) (All,c,COMM)(All,r,REG)  INCPAR(c,r) = sum(i,TRAD_COMM:MP57(c)=i, IN57(i,r));
                                                    ! ***P&M210820!
```

Block 2: Delivering wldout_sh trends to industry technologies

```
!P&M210820*** !
Variable (all,c,COMM)(all,a,ACTS)(all,r,REG)
f_afall(c,a,r) # Gap between ind a in region r's pref shift towards c and world shift towards c#;
(all,c,COMM)  wldout_sh(c) # Shift in world preferences towards com c #;
Equation E_f_afall
(all,c,COMM)(all,a,ACTS)(all,r,REG) afall(c,a,r) = -wldout_sh(c) +f_afall(c,a,r);
                                                    ! ***P&M210820 !
```

Block 3: Declares variables to accommodate shifts in household preferences

```
!P&M210820*** !
Variable (all,c,COMM)(all,r,REG)
   a3com(c,r) # Shift in hhld pref in r towards comm c #;
(all,r,REG) ave_a3com(r) # Average pref shift in hhld pref in r, naturally zero #;
(all,i,COMM)(all,r,REG) f_a3com(i,r) # Gap between hhld in region r's pref shift towards i and world shift towards i #;
                                                    ! ***P&M210820!
```

Block 4: Adds relative preference shift to GTAP-RD equation for private consumption by commodity and region

```
Equation E_qpa
# private consumption demands for composite commodities #
(all,c,COMM)(all,r,REG)
   qpa(c,r) - pop(r)
      = sum{k,COMM, EP(c,k,r) * ppa(k,r)} + EY(c,r) * [yp(r) - pop(r)]
             !P&M210820***!  + a3com(c,r) - ave_a3com(r) ! ***P&M210820! ;
```

Block 5: Introduces wldout_sh to the determination of household preference shifts

The first equation in this block defines the average preference shift for households in region r, ave_a3com(r). This variable must be included in E_qpa in Block 4 so that preference shifts by households do not upset the requirement for the sum over commodities of household consumption expenditure in region r to equal total household expenditure in region r. The second equation allows the preference movement by households for commodity i in region r [a3com(i,r)] to be driven by wldout_sh(i). This happens when f_a3com(i,r) is exogenized and set on zero and a3com(i,r) is endogenized.

```
 !P&M210820***!
Equation E_ave_a3com # Average pref shift in hhld pref in r, naturally zero #
(all,r,REG)  ave_a3com(r) = sum(i,COMM, CONSHR(i,r)*a3com(i,r));

Equation E_f_a3com
(all,i,COMM)(all,r,REG) a3com(i,r) =  wldout_sh(i) + f_a3com(i,r);
                                                !*** P&M210820!
```

Block 6: Adds relative preference shift to GTAP-RD equation for government consumption by commodity and region

```
Equation E_qga
# government consumption demands for composite commodities #
(all,c,COMM)(all,r,REG)
   qga(c,r) = yg(r) - pgov(r) - ESUBG(r) * [pga(c,r) - pgov(r)]
    !P&M210820*** !  + f_qg(c,r) - ave_f_qg(r) !***P&M210820! ;
```

Block 7: Introduces wldout_sh to the determination of government preference shifts

The first equation in this block defines the average preference shift for government in region r, ave_f_qg(r). This variable must be included in E_qga in Block 6 so that preference shifts do not upset the requirement for the sum over commodities of government expenditure in region r to equal total government expenditure in region r. The second equation allows the preference movement by government for commodity i in region r [f_qg(i,r)] to be driven by wldout_sh(i). This happens when ff_qg(i,r) is exogenized and set on zero and f_qg(i,r) is endogenized.

```
!P&M210820***  !
Variable (all,r,REG) ave_f_qg(r) # Average preference shift for government in r, naturally zero #;
Variable (all,c,COMM)(all,r,REG)
   f_qg(c,r) # Shifter for government demand for comm c in region r #;
(all,i,COMM)(all,r,REG) ff_qg(i,r) # Gap between govt in region r's pref shift towards i and world shift towards i #;

Equation E_ave_f_qg
 (all,r,REG) ave_f_qg(r) =  sum(i,COMM, [VGP(i,r) / GOVEXP(r)] * f_qg(i,r) );
Equation E_Ff_qg
(all,i,COMM)(all,r,REG) f_qg(i,r) =  wldout_sh(i) + ff_qg(i,r);
                                               !  ***P&M210820!
```

Block 8: Defines useful variables and coefficients for result reporting

This block introduces equations, variables and coefficients that were useful in preparing the tables of results in subsection 3.3. To keep the tables to a manageable size, we report results aggregated to 7 regions. The required variables are generated in this block.

```
!P&M210820****  !
Variable
 (All,i,COMM) v_wldout(i) # World output of commodity i #;
 (All,i,COMM) pworld(i) # Average wrld market price for i #;
 (All,i,COMM) qworld(i)#  World quantity of  i #;

Equation E_v_wldout
 (All,i,COMM) sum(r,REG, Sum(a,ACTS,MAKEB(i,a,r)))*v_wldout(i) = sum(r,REG,
Sum(a,ACTS,MAKEB(i,a,r)*[pca(i,a,r)+qca(i,a,r)]) );

Equation E_pworld
 (All,i,COMM) sum(r,REG, Sum(a,ACTS,MAKEB(i,a,r)))*pworld(i)  = sum(r,REG,
Sum(a,ACTS,MAKEB(i,a,r)*pca(i,a,r)) );

Equation E_qworld
(All,i,COMM) qworld(i) = v_wldout(i) - pworld(i);

SET REG7    #  Regions aggregated to 7 #
   read elements from file GTAPSETS header "REG7";
Mapping MPR7 from REG to REG7;
Read (by_elements) MPR7 from file GTAPSETS header "MPR7";

Variable  (All,c,COMM)(All,r,REG7) qc7(c,r) # Output of commodity c in region r where r is in REG7#;

Equation E_qc7
(All,c,COMM)(All,r,REG7) Sum(rr,REG:MPR7(rr)= r,Sum(a,ACTS,MAKEB(c,a,rr)))*qc7(c,r)
                 = Sum(rr,REG:MPR7(rr)= r,   Sum(a,ACTS,MAKEB(c,a,rr))*qc(c,rr));

Coefficient
(All,c,COMM)(All,s,REG)(All,d,REG7)
VXSB7(c,s,d) #  Value of exports of c from s to d at basic prices , where d is in REG7 #;
Formula
(All,c,COMM)(All,s,REG)(All,d,REG7)
VXSB7(c,s,d) =  Sum(r,REG:MPR7(r)=d,  VXSB(c,s,r));

Variable (All,r,REG7) qgdp7(r) # GDP for regions in REG7 #;
global_qgdp  # Global real GDP #;

Equation E_qgdp7
(All,r,REG7)  Sum(rr,REG:MPR7(rr)=r, GDP(rr))*qgdp7(r)  = Sum(rr,REG:MPR7(rr)=r, GDP(rr)*qgdp(rr));

Equation E_global_qgdp
 Sum(r,REG, GDP(r))*global_qgdp =   Sum(r,REG, GDP(r)*qgdp(r) );
                                                                  !  ***P&M210820!
```

3.1.2. Resetting parameter values in GTAP-RD to bring them into line with those used in the historical simulation

We set the substitution elasticities between commodities in government consumption, ESUBG, at zero for all regions. The standard setting is one. We think that the standard setting strongly overstates the extent to which governments are likely to make decisions to change the composition of their expenditures between health, education and government services in response to changes in the prices of these commodities.

We set the substitution elasticities between primary factors in all industries in each region, ESUBVA, at 0.5. Under the standard setting, the value used for any given industry is the same across regions but varies across industries from 0.20 to 1.68. We don’t think there is a strong empirical basis this variation. In our experience the variation across industries causes difficulties in result interpretation without producing compensating insights.

We set INCPAR at the values reached in the last step (step 15) of the historical simulation. As explained in section 2, we adjusted the standard values for INCPAR(c,r) for some commodities c and regions r so as to change expenditure elasticities. Our new expenditure elasticities led to results in the historical simulation for the demand-shift variables, wldout_sh(c), that we judged to be more realistic than those obtained with the standard INCPAR values.

We set the substitution elasticity in all regions between imported gas from different sources, ESUBM("gas"), at 10.4. The standard setting is 34.4. This very high value led to computational problems. Our choice of 10.4 coincides with the standard ESUBM value for Oil.

We set the substitution elasticity in all regions between domestic gas and imported gas, ESUBD("gas"), at 5.2. The standard setting is 17.2. Our revised value maintains the GTAP convention that ESUBD(c) should be half the value of ESUBM(c).

3.2. The effects on baseline projections of trends in technology/preference variables

Table 3.1 compares average annual growth rates for outputs of the 65 GTAP-RD commodities in two baseline simulations. Both simulations are conducted in year-on-year mode for 2014 to 2017. Both use the standard GTAP-RD baseline closure from Aguiar *et al.* (2020). In this closure, growth paths in each region for real GDP, population and labor supply are exogenous. Labor supply and demand are equated through wage adjustments. The split of net national income in each region between private consumption, government consumption and saving is determined in a utility maximizing specification. World investment is equated with world saving and is allocated between regions to equalize percentage movements in expected rates of return on capital.

In our first baseline simulation, we apply shocks for each region to GDP, population and labor supply in 2015, 2016 and 2017. These shocks were obtained from Aguiar *et al.* (2020). Thus, our first simulation is a typical GTAP-RD baseline. Our second baseline simulation uses the same shocks for GDP, population and labor supply, but imposes additional shocks for the technology/preference variables, wldout_sh(c). These additional shocks are annualized versions of the wldout_sh(c) results in step 15 from the historical simulation, see column (8) of Table 2.6. For example, the shock we impose for Paddy rice in each year of the second baseline simulation is -1.066 per cent [= 100*{$(1-0.1016)^{0.1}$ - 1}].

Results for the first simulation are in the left-hand panel of Table 3.1. As a shorthand we refer to this simulation as the baseline "without" demand shifts. Results for the second simulation are in the right-hand panel. We refer to this simulation as the baseline "with" demand shifts.

3.2.1. Outputs by commodity and region

The first row of Table 3.1 shows average annual growth rates in real GDP. For any given single-country region[12], the GDP growth rate in the two panels of Table 3.1 is the same. This is because both baseline simulations adopt the same exogenous paths for GDP.

[12] For EU and Other, which we formed by aggregating from the 13-region level, there can be slight differences in GDP growth between the two panels. This reflects changes in the weighting schemes used in averaging the GDP growth rates for the constituent regions.

Table 3.1. Projected annual percentage growth from 2014 to 2017: real GDP and commodity outputs

		without commodity-using technology/preference shifts								with commodity-using technology/preference shifts							
		USA	**Canada**	**Mexico**	**China**	**Japan**	**EU**	**Other**	**World**	**USA**	**Canada**	**Mexico**	**China**	**Japan**	**EU**	**Other**	**World**
GDP		2.30	1.59	2.77	6.65	1.25	2.32	2.57	2.93	2.30	1.59	2.77	6.65	1.25	2.32	2.58	2.93
	Commodity/industry outputs																
1	Paddy rice	2.98	1.55	2.23	4.57	0.38	2.43	1.80	2.51	2.52	-0.31	0.05	2.56	-1.51	0.02	0.18	0.77
2	Wheat	2.77	4.65	3.14	5.34	0.25	1.63	2.90	3.28	1.35	4.34	1.53	2.01	-2.25	-0.87	1.64	1.43
3	Other grains	2.27	2.47	2.14	6.15	0.77	2.23	1.70	3.14	1.65	1.92	1.36	4.82	-0.02	1.51	1.11	2.31
4	Vegetables &fruit	1.80	3.59	1.81	4.80	0.44	1.39	1.88	2.95	0.77	3.06	0.29	3.21	-0.99	-0.11	0.54	1.52
5	Oil seeds	3.59	4.42	2.36	5.28	0.70	2.04	2.75	3.32	4.74	6.68	2.94	5.93	0.46	3.50	3.35	4.10
6	Cane & beet	1.99	1.96	1.84	4.20	0.92	1.46	2.92	3.37	1.73	2.64	1.27	3.89	0.88	0.95	2.76	3.13
7	Plant fibres	3.51	2.61	2.91	7.31	2.53	3.79	2.92	3.83	-2.51	-3.07	-2.76	0.92	-4.43	-3.54	-2.37	-1.75
8	Other crops	2.39	3.99	2.57	6.11	1.10	2.32	2.62	2.91	3.34	6.05	2.49	6.17	1.76	3.38	3.01	3.46
9	Cattle	2.02	2.09	2.08	6.37	0.44	1.94	1.71	2.78	1.47	1.34	1.15	5.07	-1.07	0.87	0.57	1.72
10	Other animal prods	2.25	2.38	2.28	5.16	0.79	2.30	1.94	3.21	1.70	1.59	1.78	4.54	0.36	1.66	1.12	2.54
11	Raw milk	2.09	1.56	2.19	4.53	1.14	1.91	2.44	2.39	2.01	1.32	1.91	4.31	0.96	1.35	1.94	1.96
12	Wool	3.15	3.42	3.77	5.09	1.31	1.52	3.42	3.53	-8.59	-5.99	-12.58	-5.43	-14.05	-12.55	-0.57	-2.46
13	Forestry	2.57	1.69	2.80	6.89	1.07	2.20	3.52	3.83	-1.38	-0.77	-0.56	2.35	-2.85	-1.91	-0.11	-0.04
14	Fishing	2.14	2.02	2.13	5.10	1.20	1.75	2.40	3.41	1.07	1.03	1.13	3.71	0.29	0.61	1.25	2.18
15	Coal	1.96	2.48	2.16	6.00	0.25	1.12	4.68	4.63	-0.04	0.86	0.27	3.59	-2.03	-1.03	2.81	2.52
16	Oil	0.40	0.44	-0.02	3.27	-1.43	-2.92	4.02	3.14	-1.49	-0.95	-2.38	0.67	-4.08	-4.77	2.47	1.47
17	Gas	0.95	1.33	1.44	2.42	-1.82	-2.11	3.01	2.51	0.79	1.60	0.53	4.58	-2.28	-2.05	3.25	2.71
18	Other mining	2.07	1.51	3.70	6.85	0.03	2.34	4.25	4.71	1.02	1.19	3.34	5.54	-1.25	1.11	3.31	3.64
19	Cattle meat	2.02	1.81	2.13	6.11	0.43	1.82	1.77	2.09	2.99	2.47	2.69	6.36	0.46	1.99	2.16	2.56
20	Other meat	2.20	2.18	2.57	6.81	0.58	2.20	2.07	3.47	3.69	3.25	4.30	8.35	2.22	3.27	3.40	4.83
21	Vegetable oils	1.63	2.57	2.01	5.26	0.96	1.67	3.03	3.30	4.07	5.45	3.87	6.79	2.72	3.84	4.76	5.10
22	Milk products	2.11	1.52	2.22	4.92	1.04	1.80	2.29	2.27	3.21	2.50	3.11	6.00	2.13	2.50	3.42	3.26
23	Processed rice	2.22	1.45	1.95	4.56	0.35	1.69	2.11	2.97	0.74	0.50	0.98	3.66	-0.47	-0.18	1.35	2.14
24	Sugar	2.04	1.62	2.12	5.65	1.02	1.58	2.68	2.66	1.94	1.11	1.38	5.16	1.15	1.11	2.42	2.37
25	Other food	2.22	1.95	2.52	6.05	1.16	2.06	2.53	2.99	3.32	3.28	3.69	7.33	2.51	2.89	3.93	4.19
26	Bev & tobac prods	2.34	1.72	2.55	6.71	1.33	2.10	2.66	3.32	3.44	2.68	3.58	7.60	2.53	3.12	3.79	4.36
27	Textiles	1.68	0.82	1.79	7.09	-0.32	0.38	3.52	4.64	1.10	-0.14	2.10	7.62	-1.90	-1.06	4.92	5.06
28	Apparel	1.86	0.42	2.68	8.48	-0.03	0.79	3.27	4.79	2.54	1.45	3.57	9.74	0.62	0.80	5.02	5.99
29	Leather	0.93	0.34	2.14	6.47	-0.45	0.23	2.22	3.47	1.88	2.46	3.18	8.27	0.08	0.37	3.70	4.78
30	Lumber	2.75	1.53	2.97	7.16	1.17	2.33	1.91	3.44	2.14	3.93	3.11	6.63	0.65	1.70	1.56	2.98
31	Paper & p prods	2.14	1.99	2.53	6.96	0.97	1.86	3.02	3.10	0.95	1.92	1.76	5.64	-0.35	0.71	2.18	1.99
32	Petroleum & coke	1.84	1.53	2.24	5.97	1.39	2.05	3.68	3.26	0.40	-0.06	0.27	3.68	0.08	1.03	1.96	1.63

Table 3.1 continues …

Table 3.1 continued …

		without commodity-using technology/preference shifts								with commodity-using technology/preference shifts							
		USA	**Canada**	**Mexico**	**China**	**Japan**	**EU**	**Other**	**World**	**USA**	**Canada**	**Mexico**	**China**	**Japan**	**EU**	**Other**	**World**
33	Chemical prods	1.53	1.81	1.85	6.52	0.85	0.12	4.80	3.66	1.85	3.44	1.98	6.61	3.28	0.68	6.44	4.46
34	Pharmaceuticals	2.23	2.93	2.43	6.89	0.93	-0.04	5.12	2.90	2.65	4.26	2.74	7.00	1.14	0.28	5.51	3.21
35	Rubber &plas prods	1.93	1.55	2.44	7.12	0.43	1.35	3.02	3.60	2.52	2.65	2.94	7.43	0.75	1.89	3.96	4.18
36	Non-met min prods	2.37	1.47	3.59	6.78	1.01	2.70	1.85	4.20	2.65	1.90	4.56	7.12	1.37	2.89	2.24	4.54
37	Iron & steel	1.64	1.30	2.57	6.97	0.61	0.68	3.79	4.23	1.38	2.06	2.96	7.04	0.25	0.46	4.09	4.25
38	Non-ferrous metals	0.45	0.30	0.79	7.53	-0.60	-1.90	5.86	4.46	-0.10	2.52	0.82	7.11	-1.28	-2.46	6.56	4.39
39	Fab metal prods	2.14	1.41	2.72	7.22	0.83	1.74	2.82	3.39	2.19	1.54	2.94	7.14	0.43	1.47	2.86	3.30
40	Computers &electro	0.82	0.24	0.87	7.15	-1.32	-0.84	4.14	3.63	1.99	1.39	1.30	6.45	-1.59	-0.39	5.11	3.87
41	Electrical equip	1.75	1.35	1.63	7.69	-0.19	0.45	3.50	3.70	2.01	2.27	1.76	7.76	-0.65	0.44	4.22	3.88
42	Other machiney	2.29	1.92	3.18	7.74	0.80	1.39	3.72	3.98	2.08	2.58	3.19	7.41	0.11	0.82	3.60	3.64
43	Motor vehicles	2.62	2.81	3.29	7.18	0.85	1.95	3.10	3.40	3.49	3.30	4.33	7.51	0.42	2.72	3.69	3.94
44	Other transp equip	2.44	2.91	4.09	8.04	1.45	1.12	3.20	3.31	2.59	3.71	4.85	8.33	0.99	1.55	3.86	3.64
45	Other manu	1.79	1.25	2.28	7.58	0.74	1.58	3.53	3.30	2.25	3.01	3.58	8.37	1.00	2.04	4.58	4.02
46	Electricity	2.18	1.58	2.56	6.54	1.18	1.81	3.49	3.31	1.32	0.83	1.66	5.30	0.26	0.75	2.65	2.35
47	Gas distribution	1.94	1.59	2.39	5.80	0.92	1.47	3.21	2.60	0.59	0.54	0.88	5.00	0.09	0.45	1.82	1.29
48	Water	2.27	1.45	2.78	6.77	1.12	2.21	1.95	2.63	2.07	0.81	2.53	6.08	0.67	1.57	1.54	2.17
49	Construction	3.03	1.41	5.27	6.86	2.48	4.72	0.92	3.55	2.92	0.90	5.71	6.88	2.64	4.47	0.69	3.42
50	Trade	2.32	1.53	3.04	6.93	1.27	2.33	2.54	2.82	1.43	0.47	2.28	5.67	0.34	1.35	1.60	1.85
51	Hotels & restaurant	2.26	1.48	2.91	6.40	1.25	2.41	2.52	2.61	1.46	0.51	1.93	5.36	0.64	1.49	1.62	1.73
52	Land & pipe transp	2.20	1.62	2.73	6.61	1.24	2.14	3.00	3.12	2.36	1.87	3.08	6.40	1.26	2.21	3.12	3.18
53	Water transport	2.25	1.86	2.73	5.59	2.64	2.39	3.33	3.25	1.49	2.18	2.03	4.77	2.06	2.61	2.79	2.87
54	Air transport	2.07	1.52	2.33	6.12	1.27	2.13	2.82	2.68	3.96	4.38	4.48	7.62	2.93	5.76	4.90	5.05
55	Warehousing	2.08	1.64	2.77	6.70	1.17	1.84	3.33	3.22	1.02	0.76	1.90	5.40	0.10	0.76	2.32	2.13
56	Communications	2.33	1.59	2.72	6.72	1.55	2.79	2.13	2.82	2.28	1.47	2.73	6.64	1.58	2.75	2.06	2.77
57	Oth financ intermed	2.31	1.69	2.82	6.90	1.39	1.93	2.95	3.08	2.74	2.03	3.16	7.03	1.81	2.20	3.30	3.40
58	Insurance	2.25	1.98	2.85	6.41	1.23	1.94	2.68	2.47	2.04	1.52	2.62	5.81	1.08	1.55	2.30	2.15
59	Real estate	2.31	1.64	2.88	6.97	1.41	2.30	2.94	2.79	1.99	1.28	2.51	6.62	1.22	2.05	2.72	2.52
60	Other bus services	2.31	1.66	2.86	6.94	1.29	2.43	2.35	2.77	1.95	1.25	2.56	6.46	0.80	2.07	1.85	2.36
61	Rec & oth services	2.26	1.66	2.70	6.32	1.30	2.21	1.72	2.51	1.66	0.98	1.89	5.18	0.64	1.46	0.86	1.76
62	Other service govt	2.29	1.40	2.99	6.85	1.22	2.52	1.08	2.42	2.03	1.10	2.51	6.27	0.92	2.11	0.50	2.00
63	Education	2.30	1.45	3.03	6.81	0.95	2.39	1.14	2.42	1.79	0.93	2.34	5.91	0.28	1.72	0.35	1.75
64	Health &soc. work	2.28	1.39	3.00	6.78	1.20	2.54	1.06	2.41	1.85	0.94	2.41	6.09	0.86	2.02	0.34	1.87
65	Dwellings	2.62	2.10	2.87	6.71	1.69	2.17	4.24	3.18	3.07	2.39	3.06	6.71	2.18	2.56	4.61	3.55

The GDP row is a point of reference, allowing quick identification of the industries that have good growth prospects and poor growth prospects within their region. For example, looking at the left-hand panel, we see that in the baseline without demand shifts fast-growing industries for the U.S. are Oil seeds, Plant fibers and Wool. Each of these industries has a growth rate of more than 3 per cent, whereas the GDP growth rate is only 2.3 per cent. Slow-growing industries for the U.S. in the baseline without demand shifts are Oil, Gas, Non-ferrous metal prods and Computers and Electronics. Each of these industries has a growth rate of less than one per cent.

Now looking at the U.S. column in the right-hand panel, we see that the introduction of the demand shifts produces a radically different picture. While the U.S. GDP growth rate remains at 2.3 per cent, Plant fibers and Wool are now given poor growth prospects , -2.51 per cent and -8.59 per cent. Oil seeds retains its place as the strongest growing industry (now 4.74 per cent) and is joined in the over 3 per cent group by: Other crops (3.34); Other meat (3.69); Vegetable oils (4.07); Milk products (3.21); Other food (3.32); Beverages & tobacco (3.44); Motor vehicles (3.49); Air transport (3.96); and Dwellings (3.07). Apart from Plant fibers and Wool, there are 10 other U.S. industries in the right-hand panel that are now in the under 1 per cent group. These are: Vegetables & fruit (0.77); Forestry (-1.38); Coal (-0.04); Oil (-0.49); Gas (0.79); Processed rice (0.74); Paper & paper prods (0.95); Petroleum & coke (0.40); Non-ferrous metal prods (-0.10); and Gas distribution (0.59).

The story for the U.S. in Table 3.1 is repeated for all the other regions: the introduction of demand shifts into the baseline sharply changes the growth rates and rankings of industries and widens the dispersion. When we regress the “with” results for region r in Table 3.1 against the corresponding “without” results, the R^2 values are low, averaging 0.16 over the 7 regions. As we go from the column of “without” results for a region to the corresponding column of “with” results the variance of the industry growth rates increases for all regions, by factors of between 3 and 10. The lack of correlation between the “with” and “without” industry results and the increase in dispersion is illustrated at the world level by Figure 3.1.

For most commodities, the effect on simulated growth in world output of introducing the demand shifts is straight forward: an *x* per cent annual demand shift for a commodity generates approximately *x* percentage points of extra growth. However, as illustrated in Figure 3.2, this relationship is not perfect. For example, the annual demand shift for Oil seeds is -0.35, yet the introduction of demand shifts increases its world growth rate by 0.78 percentage points (from 3.32 per cent in the left-hand panel of Table 3.1 to 4.10 per cent in the right-hand panel). For Oil seeds the negative direct effect of its own demand shift is outweighed by extra growth in its main customer, the downstream product Vegetable oils. The demand shift for Vegetable oils is positive, generating an increase in the growth rate of its world output (from 3.30 per cent in the “without” baseline to 5.10 per cent in the “with” baseline).

Although demand shifts for commodity c are imposed uniformly across users and regions, their effects on regional growth rates for commodity c are far from uniform. Again we look at the case of Oil seeds. While its world growth rate is increased by 0.78 percentage points, the growth rate in Canada is increased by 2.26 percentage points (from 4.42 per cent to 6.68 per cent) and that in Japan is decreased by 0.24 percentage points (from 0.70 per cent to 0.46 per cent). We traced these diverse effects for Oil seed production in Canada and Japan

Figure 3.1. Percentage baseline growth rates for world commodity outputs with and without technology/preference demand shifts (world results from Table 3.1)

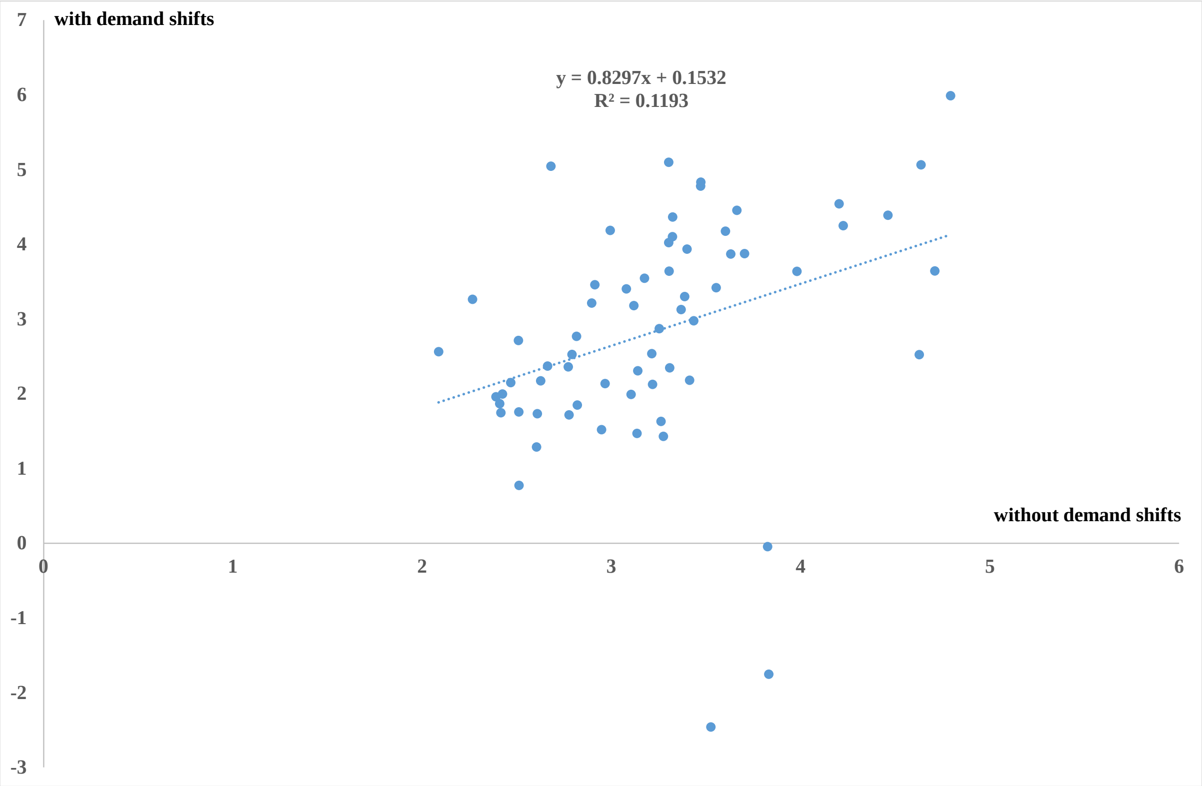
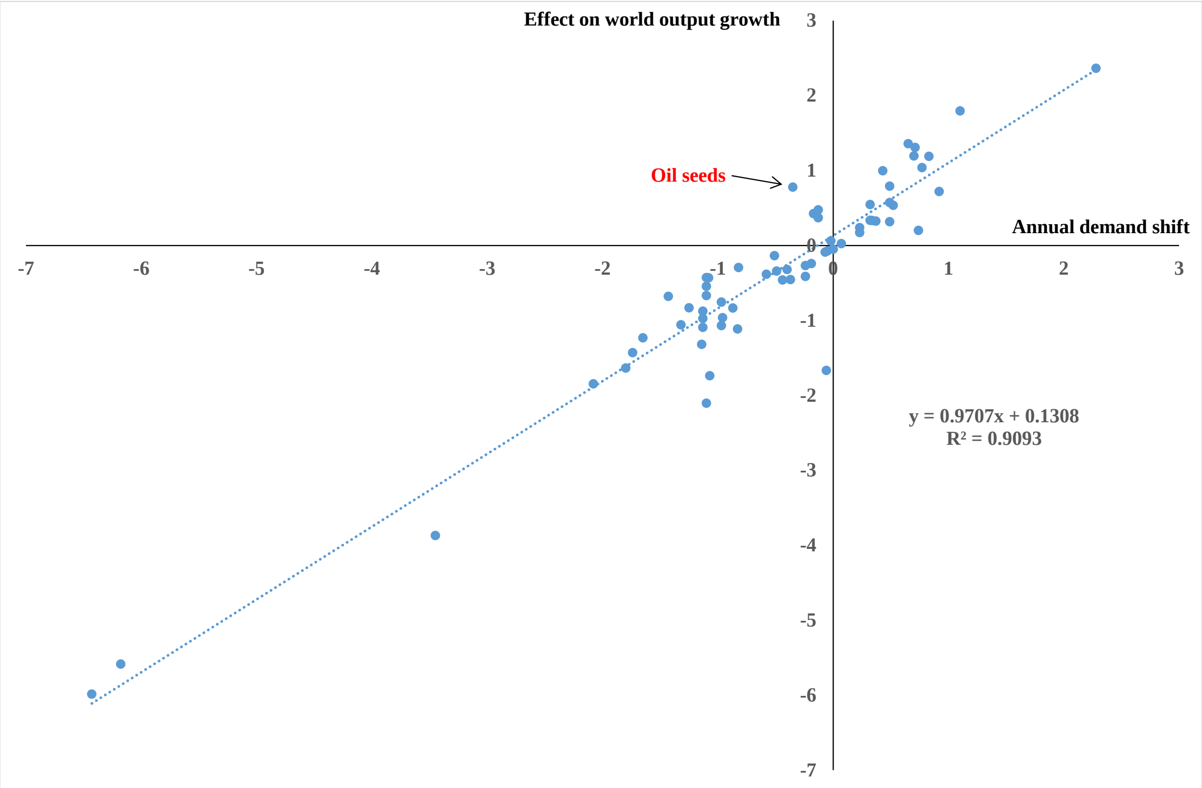


Figure 3.2. Percentage point differences in world output growth rates for commodities between the "with" and "without" baselines plotted against annual percentage demand shifts



to movements in their real exchange rates. The demand shifts are negative for Lumber, Paper, Oil and Petroleum & coke. All these products are important exports for Canada. Reductions in their world demand reduce Canada's real exchange rate with positive effects for Canada's production of other tradeable products such as Oil seeds. Japan is a major importer of Oil and Petroleum & coke. The negative demand shifts for these commodities reduce their prices. This strengthens Japan's real exchange rate in the "with" baseline relative to the "without" baseline. The higher real exchange rate reduces Japan's ability to produce Oil seeds and other tradeable products.

Whereas the diversity across regions in the response of Oil seed production to the introduction of the demand shifts is supported by an economically realistic explanation, this is not true for all commodities. Take the case of Wool. The demand shift against Wool that we bring in from Step 15 of the historical simulation is -6.44 per cent per year [=100*((1-0.4858)$^{0.1}$ – 1)]. This reduces the average annual growth rate for world Wool output by 5.99 percentage points (from 3.53 per cent to -2.46 per cent). The reduction for the region Other is only 4.00 percentage points (from 3.43 to -0.57 per cent), while the reductions in all the remaining regions are substantially more than 5.99 percentage points. On inspecting the data we found that 22 per cent of the costs of Wool production in the region "Other" is accounted for by inputs of Wool. In the remaining regions, inputs of wool are a negligible fraction of the costs of producing Wool. Given that we have treated negative demand shifts for intermediate inputs as input-saving technical changes, Wool producers in the region Other gain a major cost advantage in the transition from the left-hand panel of Table 3.1 to the right-hand panel. The Wool-Wool data items causing this result seem spurious. More generally, analyzing results from historical and corresponding baseline simulations is a powerful method for locating modelling problems.

3.2.2. Trade matrices: towards a trade baseline

At various times, there have been discussions at the U.S. International Trade Commission about the feasibility of creating a trade baseline. This would show how exports and imports for each commodity and pair of regions would evolve under business-as-usual assumptions. Historical simulations of the type described in this paper could be an input to the creation of a trade baseline.

Table 3.2 is presents examples of a trade matrices from the GTAP-RD baselines. Each of the three matrices in the table is for U.S. exports. Part A of table shows GTAP-RD data for 2014. Parts B and C are projections for 2017 from our baseline GTAP-RD simulations "without" and "with" commodity-using technology/preference shifts. The components of the matrices are percentages of total U.S. exports. For example, the first component in Table 3.2A means that 1.26 per cent of the value of U.S. exports in 2014 was accounted for by exports of Chemical products to Canada. Each of three matrices identifies the commodities accounting for over 2 per cent of total U.S. exports in 2014. Minor exports are aggregated in "All other products". The row totals in the matrices are commodity percentages in U.S. exports. The column totals are destination percentages in U.S. exports.

Comparison of the destination column totals in parts A and B of Table 3.2 shows increasing percentages of U.S. exports going to China (from 10.08 to 10.87) and Mexico (from 11.28 to 11.46) and declining percentages going to Japan (from 4.51 to 4.38) and Canada (from 14.26

Table 3.2A. Percentages of U.S. exports in GTAP data for 2014

	Canada	Mexico	China	Japan	EU	Other	Total
Chemical products	1.26	1.21	0.75	0.39	1.36	2.85	***7.83***
Computers & electronics	0.78	0.81	1.20	0.41	1.35	3.06	***7.61***
Motor vehicles	2.82	1.43	0.81	0.10	0.65	1.59	***7.40***
Other machinery	1.34	1.20	0.57	0.21	0.97	3.02	***7.31***
Petroleum & coke	0.53	0.89	0.12	0.15	1.13	3.36	***6.19***
Other business services	0.14	0.01	0.30	0.43	2.98	2.11	***5.97***
Other transport equipment	0.46	0.18	1.04	0.09	1.51	2.29	***5.58***
Other financial services	0.19	0.02	0.16	0.15	2.14	0.83	***3.49***
Pharmaceuticals	0.23	0.08	0.10	0.18	1.91	0.77	***3.26***
Electrical equipment	0.66	0.88	0.20	0.11	0.47	0.94	***3.25***
Other manu (furniture)	0.42	0.26	0.25	0.22	0.81	0.97	***2.93***
Non-ferrous metal prods	0.39	0.34	0.43	0.08	0.55	0.97	***2.75***
Education	0.11	0.05	0.17	0.11	0.78	1.17	***2.38***
Recreation	0.15	0.05	0.22	0.11	0.77	0.89	***2.19***
Other transp. & travel ag.	0.05	0.02	0.28	0.04	0.93	0.85	***2.17***
Rubber & plastic prods	0.53	0.59	0.16	0.05	0.24	0.47	***2.03***
Air transport	0.12	0.04	0.17	0.19	0.78	0.71	***2.01***
All other products	4.10	3.24	3.16	1.49	4.98	8.68	***25.65***
Total	***14.26***	***11.28***	***10.08***	***4.51***	***24.33***	***35.53***	***100***

Table 3.2B. % of U.S. exports: projection to 2017 without commodity pref/tech shifts

	Canada	Mexico	China	Japan	EU	Other	Total
Chemical products	1.25	1.22	0.77	0.36	1.36	2.67	***7.63***
Computers & electronics	0.70	0.74	1.24	0.37	1.32	2.76	***7.13***
Motor vehicles	2.86	1.49	0.90	0.10	0.69	1.52	***7.57***
Other machinery	1.31	1.24	0.61	0.20	1.07	2.78	***7.21***
Petroleum & coke	0.52	0.92	0.13	0.14	1.08	3.20	***6.00***
Other business services	0.14	0.01	0.33	0.43	3.14	2.14	***6.19***
Other transport equipment	0.47	0.19	1.12	0.10	1.65	2.17	***5.68***
Other financial services	0.19	0.02	0.17	0.15	2.23	0.81	***3.58***
Pharmaceuticals	0.23	0.08	0.11	0.18	1.99	0.74	***3.33***
Electrical equipment	0.63	0.91	0.21	0.10	0.49	0.84	***3.16***
Other manu (furniture)	0.39	0.26	0.26	0.22	0.85	0.89	***2.87***
Non-ferrous metal prods	0.34	0.33	0.43	0.07	0.48	0.89	***2.54***
Education	0.11	0.05	0.19	0.12	0.81	1.27	***2.54***
Recreation	0.15	0.05	0.24	0.11	0.81	0.91	***2.27***
Other transp. & travel ag.	0.05	0.02	0.30	0.04	0.95	0.84	***2.20***
Rubber & plastic prods	0.51	0.59	0.17	0.05	0.26	0.45	***2.02***
Air transport	0.11	0.04	0.18	0.18	0.78	0.69	***1.99***
All other products	4.03	3.29	3.52	1.47	5.18	8.57	***26.07***
Total	***14.00***	***11.46***	***10.87***	***4.38***	***25.15***	***34.15***	***100***

Table 3.2C. % of U.S. exports: projection to 2017 with commodity pref/tech shifts

	Canada	Mexico	China	Japan	EU	Other	Total
Chemical products	1.26	1.21	0.75	0.35	1.34	2.59	***7.49***
Computers & electronics	0.74	0.80	1.31	0.40	1.41	2.96	***7.61***
Motor vehicles	2.95	1.57	0.95	0.10	0.73	1.59	***7.89***
Other machinery	1.28	1.25	0.61	0.20	1.07	2.75	***7.16***
Petroleum & coke	0.49	0.86	0.12	0.13	0.98	2.91	***5.48***
Other business services	0.14	0.01	0.33	0.44	3.15	2.15	***6.22***
Other transport equipment	0.48	0.19	1.13	0.10	1.66	2.16	***5.71***
Other financial services	0.19	0.02	0.17	0.16	2.28	0.83	***3.65***
Pharmaceuticals	0.23	0.08	0.11	0.18	2.03	0.75	***3.38***
Electrical equipment	0.63	0.92	0.21	0.10	0.50	0.85	***3.20***
Other manu (furniture)	0.39	0.27	0.26	0.22	0.87	0.89	***2.89***
Non-ferrous metal prods	0.34	0.33	0.41	0.06	0.45	0.86	***2.45***
Education	0.11	0.05	0.20	0.12	0.82	1.29	***2.58***
Recreation	0.15	0.05	0.24	0.11	0.81	0.90	***2.26***
Other transp. & travel ag.	0.05	0.02	0.31	0.04	0.94	0.84	***2.19***
Rubber & plastic prods	0.52	0.61	0.17	0.05	0.26	0.46	***2.06***
Air transport	0.12	0.04	0.19	0.20	0.81	0.71	***2.06***
All other products	3.93	3.26	3.50	1.48	5.12	8.42	***25.70***
Total	***13.99***	***11.54***	***10.95***	***4.43***	***25.20***	***33.90***	***100***

to 14.00). These changes are mainly a reflection of GDP growth rates: strong in China and Mexico and relatively weak in Japan and Canada. However there are other factors affecting the structure of U.S. exports in part B. The GTAP-RD baseline "without" pref/tech shifts shows real appreciation for EU based on strong investment growth relative to GDP growth. This facilitates an increase in the percentage of U.S. exports going to EU (from 24.33 to 25.15). It also explains increases in the percentages in U.S. exports of Other Business services (from 5.97 to 6.19) and Other Financial services (from 3.49 to 3.58). These commodities are over-weighted in U.S. exports to EU. Although EU accounts for only a quarter of all U.S. exports, it accounts for more than a half of U.S. exports of Other Business services and nearly a half of U.S. exports of Other Financial services.

Moving from part B of Table 3.2 to part C, we see that introduction of pref/tech shifts slightly accentuates the growth in China, Mexico and EU's percentages in U.S. exports, slightly reverses the decline in Japan's percentage, and slightly accentuates the declines of Canada and Other. These changes are small, but in some cases they are the net result of significant effects that happen to be offsetting. Consider the case of Canada. As mentioned in the discussion of the Oil seed results in subsection 3.2.1, the introduction of pref/tech shifts reduces Canada's real exchange rate. We would expect this to reduce Canada's share in U.S. exports. However, there is an offsetting effect. Motor vehicles, which receive a positive pref/tech shift in part C, are strongly over-weighted in U.S. exports to Canada. Whereas Canada accounts for 14 per cent of all U.S. exports, it accounts for 38 per cent of U.S. Motor vehicle exports.

4. Concluding remarks

When we started this project, it wasn't clear to us that it would produce realistic outcomes. We wondered whether successive GTAP databases would be sufficiently comparable to support historical simulation. Having worked closely with these data for several months, we now think they have stood up well to the rigorous interrogation that historical simulations provide. While we found cases in which the comparison of item *x* in the database for 2004 with that in the database for 2014 implied an implausible change (see for example the discussion of Processed rice in subsection 2.3.2), these cases were quite few. We also think that GTAP's standard parameter settings worked well in the historical simulation, although as set out in Tables 2.7 and 2.8 and subsection 3.1.2 we made some adjustments. One problem that we had with GTAP was that some of the industries were too heterogeneous. A key example is Other mineral products, which combines traded products such as Iron ore, Alumina, Uranium and Gold with non-traded products such as Road materials. This degree of heterogeneity inhibited our ability to assemble data on quantities and prices for use in the historical simulation (see the discussion of Table 2.9).

Another cause for concern at the start of the project was whether we would be able to find suitable closures in a global model to absorb movements in a worthwhile collection of variables. To absorb quantity and value movements for commodity outputs, we added preference/technology demand-shift variables to standard GTAP, and then endogenized them. This worked satisfactorily. What we found more difficult was absorbing macro information on movements in real exchange rates (price levels in different countries expressed in a common currency). Even after introducing into the historical simulation terms-of-trade movements and movements in savings relative to investment in each region, we still needed to rely heavily on the Balassa-Samuelson mechanism. This left us with seemingly quite extreme movements for some regions (especially China and Japan) in productivity for industries producing non-traded commodities relative to those producing traded commodities (see Table 1.1).

Historical simulation is a step-by-step process. At each step we add data items, change the closure, compute a solution, check and interpret results, and plan the next step. There is a never ending list of possible steps. But as a practical matter, we must stop every now and again to report findings. After 15 steps in this project we have produced what we think are robust results (not likely to be changed substantially by further steps) for 2004 to 2014 in worldwide preference/technology shifts at the GTAP commodity level. We found: shifts against the use of natural fibres (Plant fibres and Wool) in the production of Textiles; shifts against Forestry and Paper & paper products; a shift against Coal and shifts in favor of Oil and Gas; a shift against Petroleum consistent with improved efficiency in cars and against Electricity consistent with improved efficiency of electrical equipment; shifts against direct consumption of most farm products in favor of consumption of processed food products; and shifts in favor of Apparel, Leather products, Motor vehicles, Electronic equipment, Air transport and Financial intermediation.

Including extrapolated versions of these shifts in a baseline simulation causes a radical change in the projected picture for the industrial composition of output in each country. When we regressed growth rates for industries in country r generated in a baseline simulation *with* demand shifts against growth rates generated *without* demand shifts, the R^2s averaged only 0.16 across the seven regions reported in section 3. Consistent with our earlier work on the U.S.[13], we are forced to the conclusion that baselines relying only on macro projections are unlikely to give a useful picture of movements in industry structure.

There are several directions in which the research in this paper could be taken. First, we could conduct additional steps in the historical simulation to introduce further data items. One obvious possibility is commodity outputs by region, not just the world as in the current historical simulation. Another possibility is to introduce data on employment and wage rates by industry and region with the hope of improving the realism of the non-traded/traded productivity estimates.

A second direction is decomposition analysis. Movements in preference and technology variables estimated from an historical simulation can be fed back as exogenous shocks into the model. This gives us an analysis of the relative quantitative significance of different causation factors in the development in the economy.

A third direction is to perform update exercises. As described in section 1, updating input-output databases was the original motivation for historical simulations. The baseline simulation with preference/technology trends can be thought of as producing a GTAP database for 2017. This could be extended to a business-as-usual picture of 2020, which could become the starting point for analyzing the effects of COVID.

A fourth direction is validation. As well as the 2004 and 2014 databases, there are also GTAP databases for 2011 and 2007. It would be possible to conduct an historical simulation from 2004 to 2011 (2004 to 2007 is probably too short a period). Then we would project to

[13] See for example Dixon and Rimmer (2010 & 2013) in which we show that improvement in forecast performance at the industry level depends heavily on the inclusion of realist preference/technology shifts, and only marginally on accurate macro forecasts.

2014 using results from the 2004-11 historical simulation and other information available *in* 2011, but not later. The projections derived this way for 2014 could be checked against the database for 2014, allowing us to assess the performance of the historical-baseline method.[14]

A fifth direction is the development of the trade-baseline idea outlined in subsection 3.2.2. This would involve systematic analysis of trade matrices such as those in Tables 3.2A-C, with a view to isolating determining factors such as regional growth rates, real exchange rate movements, and changes in terms of trade. Projected trade matrices would then become the baseline in projections of the likely effects of bi-lateral and multi-lateral trade agreements and other trade policies such as those aimed at reducing reliance on global supply chains.

Appendix 1. Data sources for percentage movements between 2004 and 2014 in world quantities and prices for GTAP commodities

A1.1 Data used in step 14

In step 14 we introduced percentage quantity movement between 2004 and 2014 for 31 GTAP commodities. In this subsection we list data sources and our own data preparation files.

Data sources:

The Food and Agriculture Organization (FAO) publishes annual world quantities for numerous farm and processed food products, see http://www.fao.org/faostat/en/#data . We used these data to compile estimates of percentage quantity movements between 2004 and 2014 in 22 agricultural, forestry, fishery and downstream manufactured commodities. Data for the agricultural commodities (coms 1 to 12, 19 to 24) were obtained from FAO production statistics available at http://www.fao.org/faostat/en/#data . Data for forestry commodities (coms 13, 30 and 31) were obtained from FAO forestry yearbooks available at http://www.fao.org/forestry/statistics/80570/en/ . Data for fishery production (com 14) were obtained from FAO yearbooks of Fishery and Aquaculture statistics available at http://www.fao.org/publications/search/en/?serialtitle=RkFPIFlIYXJib29rLiBGaXNoZXJ5IGFuZCBBcXVhY3VsdHVyZSBTdGF0aXN0aWNz .

We obtained estimates for production of coal, oil, gas and electricity (coms 15, 16, 17 and 43) from Our World in Data (see Richie, 2014) and the International Energy Association (IEA), see https://www.iea.org/subscribe-to-data-services/electricity-statistics . We also looked up production data on petroleum products and coke (com 32) from the IEA (https://www.iea.org/data-and-statistics/data-tables?country=WORLD&energy=Oil&year=2014) and Statista (https://www.statista.com/statistics/267891/global-coke-production-since-1993/). These latter two sources imply growth for petroleum products between 2004 and 2014 of 5.33 per cent and for Coke of 60.27 per cent. Coke is a small fraction of the combined Petroleum & coke product. On this basis we know that the appropriate growth factor for Petroleum & coke must be much closer to 5.33 than 60.27. As can be seen from Table 2.6, we chose 9.67, in line with the growth factor for oil.

We obtained growth in steel output from the World Steel Association (see https://www.worldsteel.org/en/dam/jcr:1568363d-f735-4c2c-a1da-e5172d8341dd/World+steel+in+Figures+2016.pdf). We used these data for GTAP's Iron & steel sector (com 35).

[14] This validation exercise would be similar to that described for the U.S. in Dixon and Rimmer (2010 & 2013).

We obtained global output data for Water transport (com 49) from UNCTAD (see https://unctad.org/en/PublicationsLibrary/dtl2018d1_en.pdf). For Air transport (com 50), we obtained data on growth in passenger and freight air traffic from the World Bank (see https://data.worldbank.org/indicator/IS.AIR.PSGR and https://data.worldbank.org/indicator/IS.AIR.GOOD.MT.K1). Growth in air passenger services between 2004 and 2014 was 70.83 per cent and growth in air freight was 32.94 per cent. On the basis of the description in Rodrigue (2020, chapter 5) we combined these two growth rates with weights 0.85 and 0.15, giving the growth in GTAP's air transport industry as 65.14 per cent.

For global production of Motor vehicles (mvh), we used data from that International organization of motor vehicle manufacturers, known as OICA, see http://www.oica.net/category/production-statistics/2004-statistics/ .

A1.2 Data used in step 15

The metals and minerals yearbooks produced by the U.S. Geographical survey, available at https://www.usgs.gov/centers/nmic/minerals-yearbook-metals-and-minerals contain data on quantity outputs and prices of many mineral products. We use these data to build up a partial picture of world output and price movements between 2004 and 2014 for the GTAP commodity Other mining (see Table 2.9).

From Indexmundi.org (available at https://www.indexmundi.com/commodities/?commodity=rice&months=300), who used U.S. Department of Agriculture and World Bank data, we estimated that the price increase between 2004 and 2014 for Processed rice was 69.43 per cent.

We estimated that between 2004 and 2014, worldwide consumption of wheat grew by 24.51 per cent. This was based on growth in wheat as a feed stock, see https://research.rabobank.com/far/en/sectors/grains-oilseeds/global_wheat_demand_article_1.html). Subsequently, too late to use in this project, we found data on consumption growth for all purposes, which was about 20 per cent (see http://joannenova.com.au/2016/09/record-hottest-year-means-record-bumper-wheat-crop/).

From Ritchie and Rosser (2017, 2019) we obtained data on slaughter numbers (heads) and production (tonnes) for cattle & buffalo, pigs and chickens & turkeys, (see https://ourworldindata.org/meat-production#number-of-animals-slaughtered). We used these data in setting the revised quantity growth numbers for Cattle, Other animal prods, and Other meat.

A1.3 Storage of data processing worksheets

For the most part, the commodity classifications in the data sources cited in subsections A1.1 and A1.2 are finer than those in the GTAP model. For example, the GTAP category Oil seeds (osd) has at least 15 components in the FAO dataset used to estimate its quantity growth. Consequently, we had to make many mapping and aggregation decisions. To keep track of this work we stored spreadsheets identified as follows.

Step 14:

The Directory for these spreadsheets is H:\dixon\consult\ITC\2020\Baseline:

fsh WORK_ITC_270720.xlsx, sheet 1

frs, lum, ppp WORK_ITC_270720.xlsx, sheet round wood

pdr FAOSTAT_data_7-20-2020 pdr.xlsx

wht FAOSTAT_data_7-21-wht.xlsx

gro FAOSTAT_data_7-21-2020 gro.xlsx

v_f FAOSTAT_data_7-23-2020 v_f.xlsx

osd FAOSTAT_data_7-21-2020 osd.xlsx

c_b FAOSTAT_data_7-25-c_b.xlsx

pfb FAOSTAT_data_7-25-pfb.xlsx

ocr FAOSTAT_data_7-24-ocr.xlsx

ctl FAOSTAT_data_7-24 ctlnew.xlsx

oap FAOSTAT_data_7-24-oapnew.xlsx

rmk FAOSTAT_data_7-21-2020 rmk.xlsx

wol FAOSTAT_data_7-24-wol.xlsx

cmt FAOSTAT_data_7-24-cmt.xlsx

omt FAOSTAT_data_7-24-omt.xlsx

vol FAOSTAT_data_8-1-2020-vol.xlsx

mil FAOSTAT_data_7-25-mil.xlsx

pcr FAOSTAT_data_7-25-2020 rice pcr.xlsx

sgr FAOSTAT_data_7-25-sgr.xlsx

coa, oil, gas global_primary_energy.xlsx

ely Electricity generation by source – world.xlsx

p_c WORK_ITC_280720.xlsx, sheet IEA

i_s https://www.worldsteel.org/en/dam/jcr:1568363d-f735-4c2c-a1da-e5172d8341dd/World+steel+in+Figures+2016.pdf

atp API_IS_AIR.PSGR_DS2_en_excel_v2_1217936.xlsx and

wtp API_IS_AIR.GOOD.MT.K1_DS2_en_excel_v2_1217937.xlsx

mvh from http://www.oica.net/category/production-statistics/2004-statistics/ for global production of MVP. We used the total vehicle productions for 2004 ad 2014 (64,496,220 and 89,776,465).

Step 15:

The Directory for these spreadsheets is H:\dixon\consult\ITC\2020\Baseline:

ctl, oap, omt Animals-slaughtered-for-meat&production.xlsx

rmk, mil Work_ITC_280720.xlsx in sheet Rmk-Mil

omn Work_ITC_280720.xlsx on sheets mining and mining2

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