Making CGE models track history: an historical simulation with GTAP

presentation by

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to

National CGE Workshop 2022
October 17, 2022
State Library Victoria Conference Centre

Plan

(1) Introduction to historical simulations with examples of historical simulations and related decomposition analysis

(2) Historical simulations and validation

(3) First attempt at an historical simulation for GTAP

1. Introduction to historical simulations

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In an historical simulation we start with a database for year t and create a database for year t + τ incorporating observed movements in a selection of variables.

Original motivation: updating input-output databases

Updating at the macro level is comparatively easy.

Tell the model what happened between year t (last published input-output table) and a more recent year (t + τ) to:

Aggregate employment – *naturally exogenous*
Aggregate capital – *endogenize the economy-wide average rates of return*
Aggregate private consumption – *endogenize APC*
Aggregate public consumption – *naturally exogenous*
Aggregate investment – *endogenize scalar in industry investment functions*
Aggregate imports – *endo preference twist between domestic and imported products*
Aggregate exports – *endogenize total factor productivity*
Terms of trade – *endogenize a scalar shift in foreign-demand curves*

In this way we can generate a CGE database that is consistent at a macro level with the data for year t + τ.

Y=A*F(K,L) **Y=C+I+G+X-M** **X=SHIFT*G(TofT)**

Adding industry and commodity detail to an historical simulation

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Household demand for commodity i

$$x(i) = \varepsilon(i) * c + \sum_{k} \eta(i,k) * p(k) + a(i), \quad i = 1,\ldots,n$$

Production function for industry j

$$Y(j) = \frac{1}{A(j)} * F_j\left(\frac{X_{1j}}{A_{1j}}, \frac{X_{2j}}{A_{2j}}, \ldots, \frac{X_{nj}}{A_{nj}}\right), \quad j = 1,\ldots,n$$

Historical and decomposition simulations to support the IC's motor vehicle inquiry of 1996

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We updated the 1987 Australian input-output table to 1994 with an historical simulation that took in data on movements between 1987 and 1994 in a variety of industry variables including:

- household purchases of motor vehicles – *endogenize household preference shift*
- output of motor vehicles – *endogenize intermediate-use technology variables*
- tariffs on motor-vehicles – *naturally exogenous*
- exports of motor vehicles – *position of foreign-demand curve for Australian motor-vehicle products*
- imports of motor vehicles – *preference twist between imported & domestic motor vehicle products*
- foreign-currency cif import price of motor vehicles – *naturally exogenous*
- employment in motor vehicles – *labour-saving technical change in motor vehicles*
- capital stock in the motor-vehicle industry – *endogenize rates of return on capital*
- investment in the motor vehicle industry – *endogenize shift in investment function*

Decomposition results for motor vehicles

The decomposition simulation showed that between 1987 and 1994 the Australian motor-vehicle industry:

- benefitted from a shift in household preferences towards cars;
- benefitted from car-using technology change throughout Australian industry;
- was harmed by a twist in preferences towards imported cars and away from domestic;
- was harmed by an adverse shift in the foreign-demand curve for cars; and
- was harmed, but only by a small extent, by reduction in protection.

Dixon, P.B., M.T. Rimmer (2002), *Dynamic General Equilibrium Modelling for Forecasting and Policy: a Practical Guide and Documentation of MONASH*, Contributions to Economic Analysis 256, North-Holland Publishing Company, pp. xiv+338.

Historical and decomposition simulations to identify the effects of NAFTA on the U.S. economy: 1992-1998

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A 502-industry version of the USAGE model of the U.S. with U.S. imports and exports of each commodity disaggregated into 3 sources and 3 destinations: Canada, Mexico and ROW. Among the variables fed into the historical simulation were:

prices, quantities and tariff rates on U.S. imports by commodity and source, and

prices, quantities and foreign tariff rates on U.S. exports by commodity and destination.

Trade effects

- growth in volume of U.S. imports from Canada 68%: NAFTA contribution 5 percentage points;
- growth in volume of U.S. imports from Mexico 241%: NAFTA contribution 144 percentage points;
- growth in volume of U.S. exports to Canada 63%: NAFTA contribution 17 percentage points;
- growth in volume of U.S. exports to Mexico 78%: NAFTA contribution 28 percentage points.

A lot of this NAFTA-related U.S. trade growth was trade diversion. NAFTA reduced U.S. trade with ROW.

- growth in volume of total U.S. imports 74%; NAFTA contribution 6 percentage points;
- growth in volume of total U.S. exports 48%; NAFTA contribution 3 percentage points.

NAFTA effects on the U.S. economy: 1992-1998

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Structural effects of NAFTA

- 236 industries suffered a negative impact.
- 266 had positive impacts.
- 26 industries had output impacts more negative than -5 per cent. But for most of these output growth was positive despite the negative NAFTA effect.
- 37 industries had negative growth. Of these, NAFTA factors contributed more than half the negative result in only 7 cases.
- Of the 16 industries that had the largest positive impacts from NAFTA, 10 had negative impacts from trade factors outside NAFTA. Thus, for these industries, NAFTA had a mitigating effect on otherwise negative trade developments.

Conclusion: NAFTA did not exacerbate structural difficulties in the U.S. economy

2. Historical simulations and validation

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Historical simulations for the U.S.: 1992-1998

preference shifts against

tobacco, malt beverages, wine & spirits, bowling centers, newspapers

preference shifts towards

boatbuilding, luggage, travel trailers, sporting clubs, cable TV

rapid technical progress in the production of

computers, financial services

slow or negative technical progress in the production of

childcare, vet services

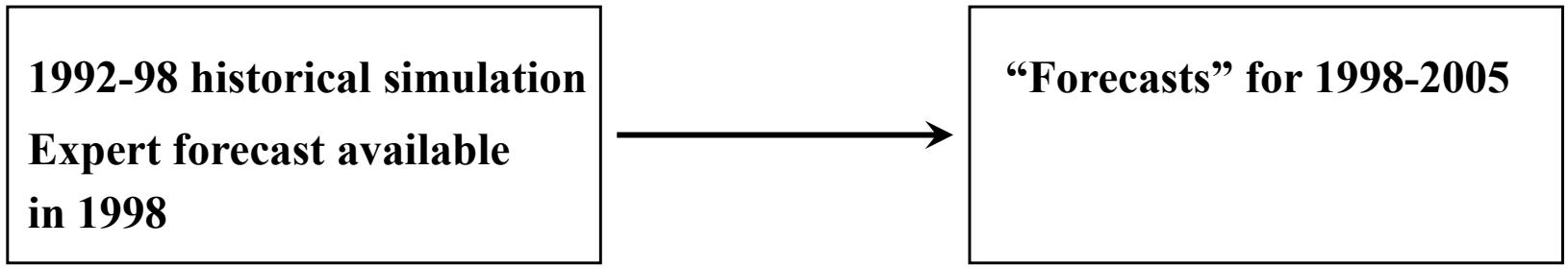
input-using technical change favoring

computers, job training, management services

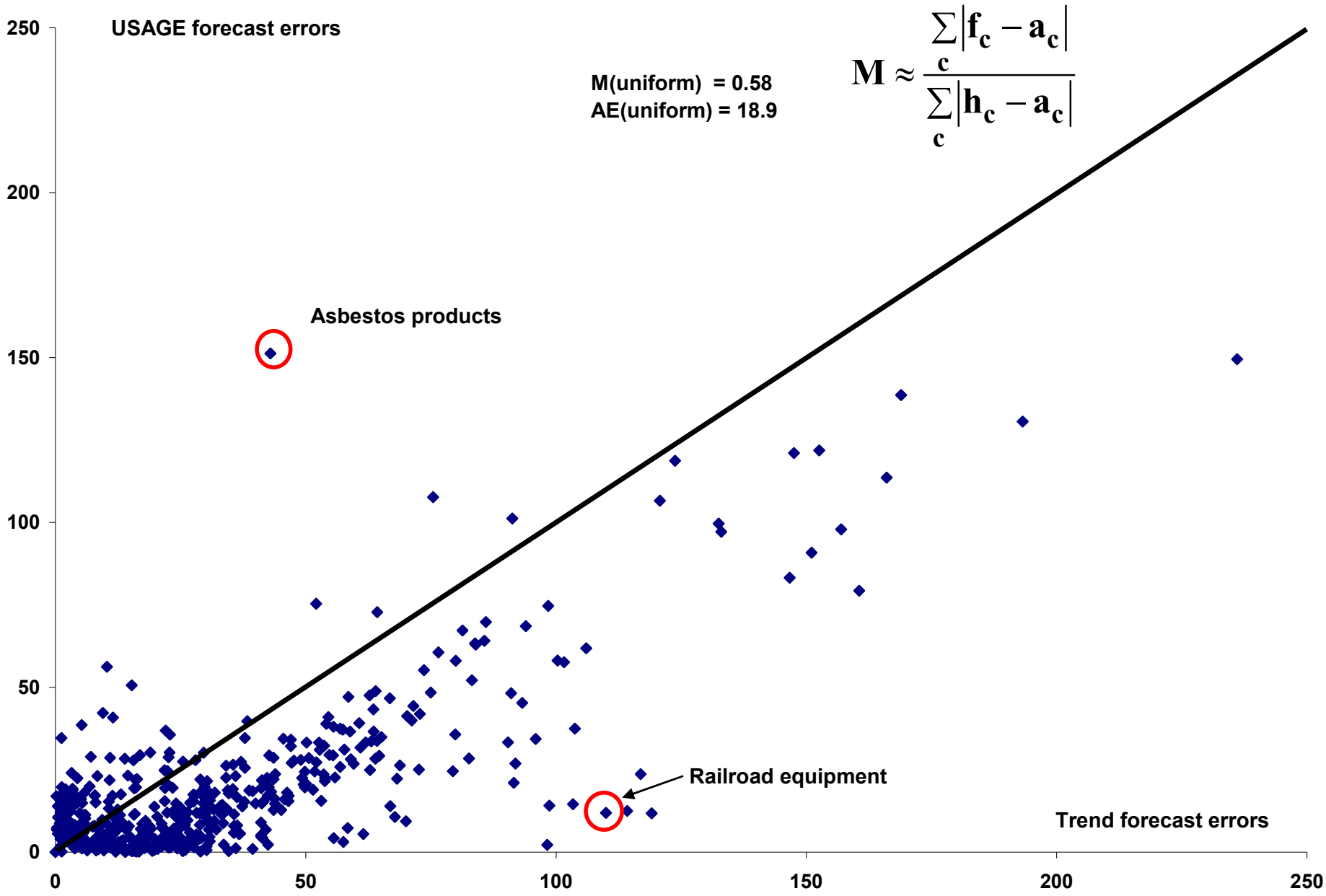
input-using technical change against

glass, sawmill products, brick & clay tiles

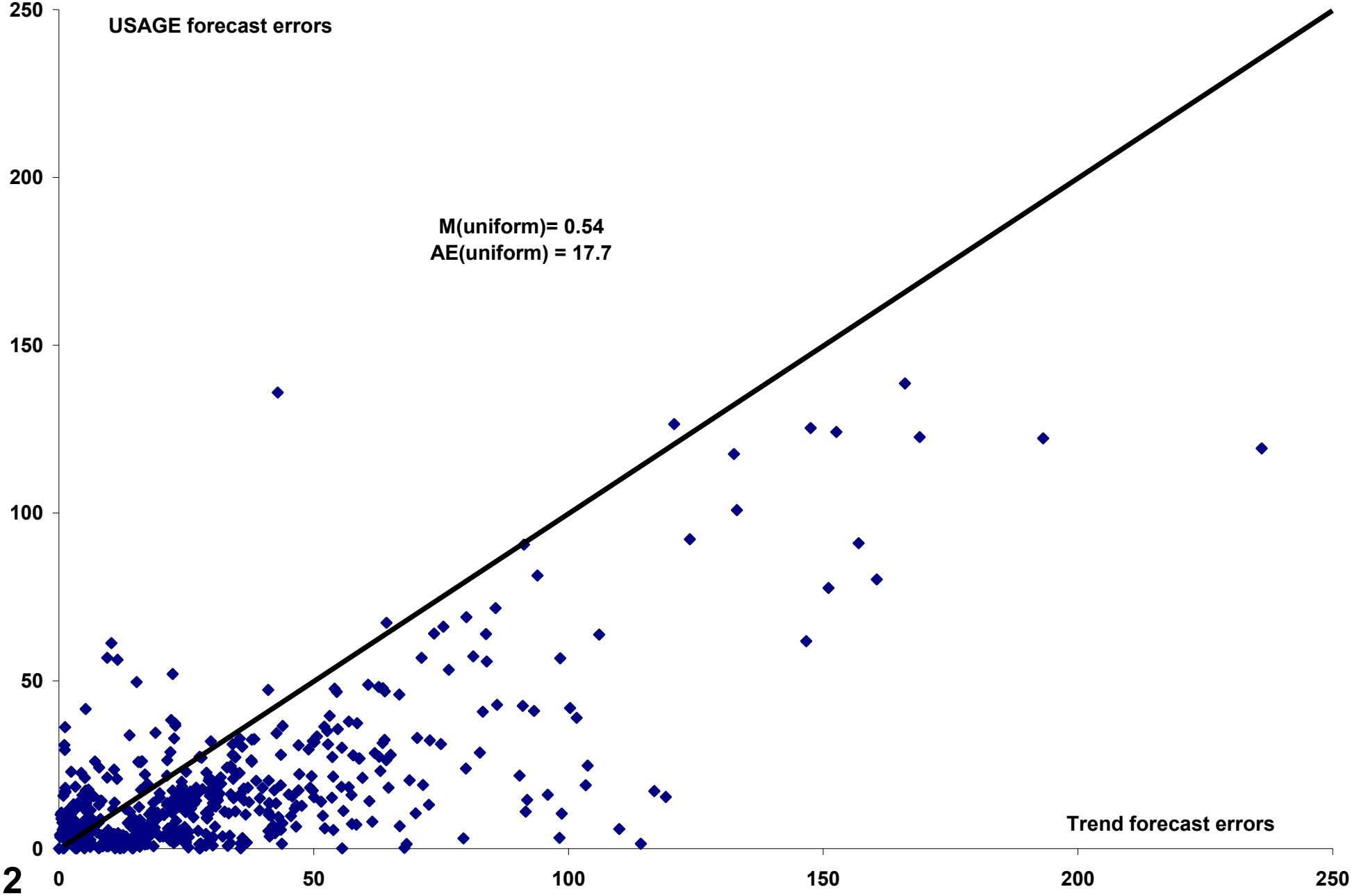
Testing the forecasting method



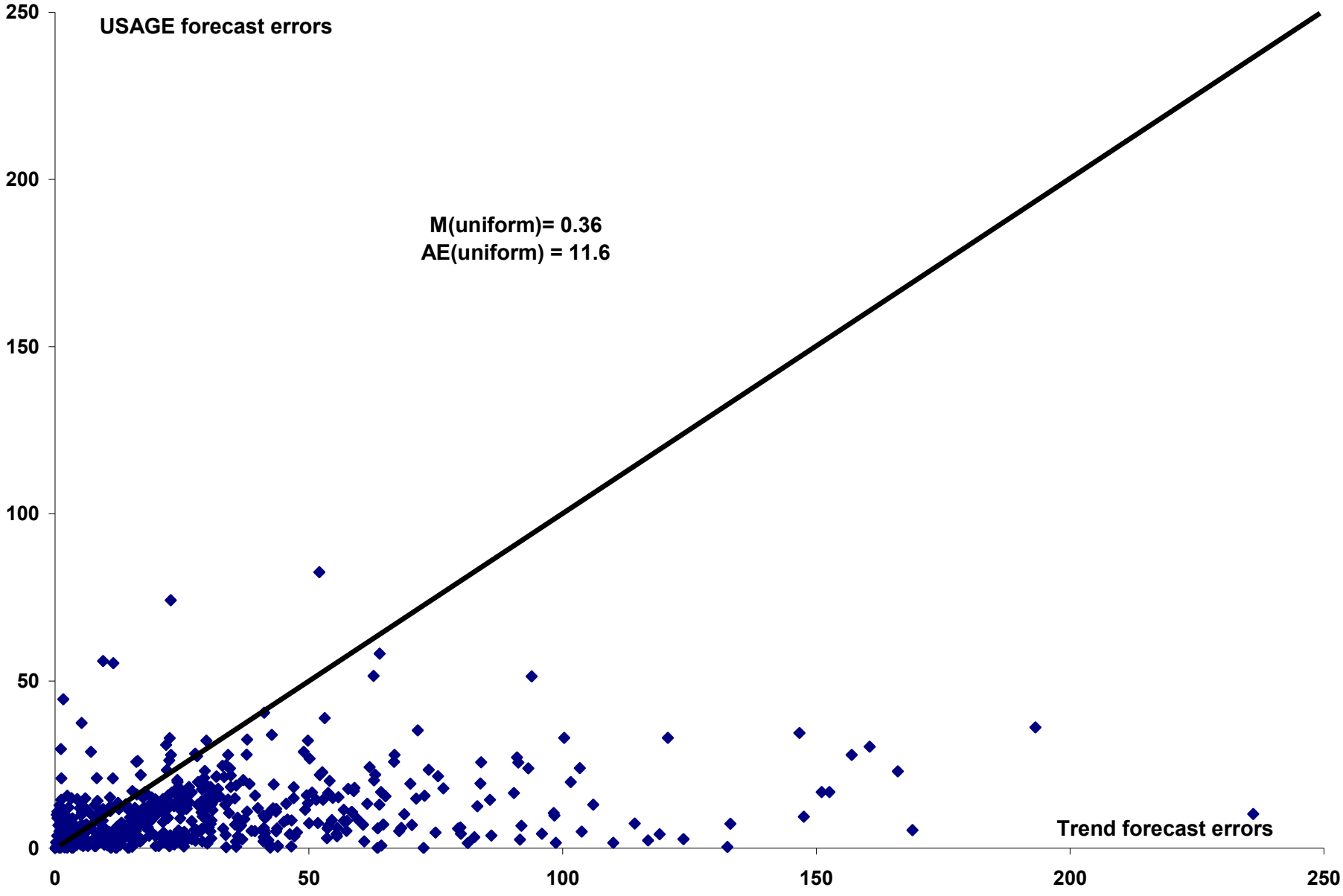
% forecast errors for commodity outputs 1998-2005: trend versus USAGE pure forecast



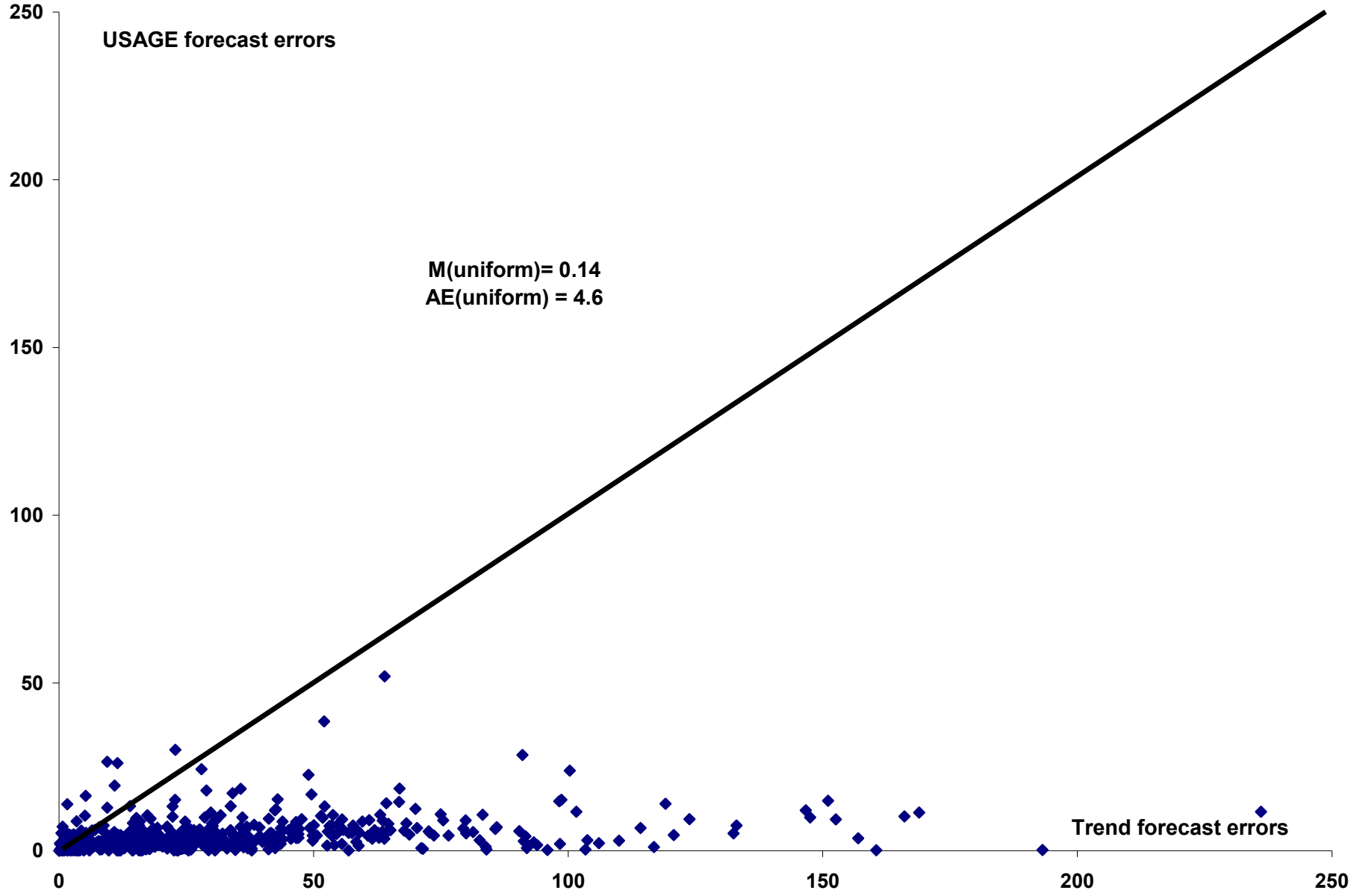
% forecast errors for commodity outputs 1998-2005: trend versus USAGE forecast with truth for macro and energy variables



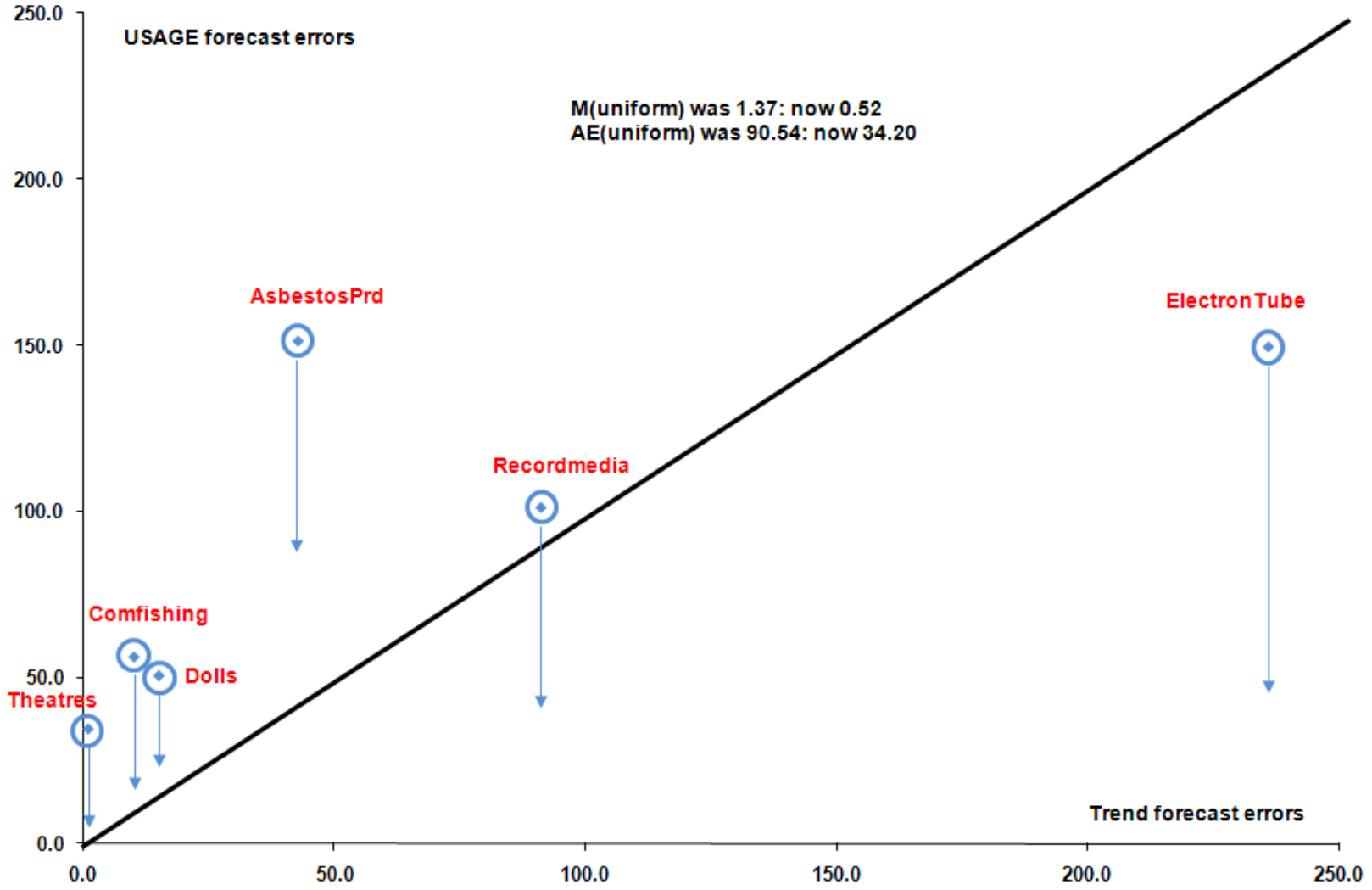
% forecast errors for commodity outputs 1998-2005: trend versus USAGE forecast with truth for macro, energy and trade variables derived from historical sim for 1998-2005



% forecast errors for commodity outputs 1998-2005: trend versus USAGE forecast with truth for macro, energy, trade & tariff, and technology & preference variables derived from historical sim for 1998-2005



Peter Mavromatis' thesis: forecast errors can be reduced by including more detailed knowledge of industries



Dixon, P.B. and M.T. Rimmer (2013), "Validation in CGE modeling", Chapter 19, pp. 1271-1330 in P.B. Dixon and D.W. Jorgenson (editors) *Handbook of Computable General Equilibrium Modeling*, Elsevier

3. First attempt at an historical simulation for GTAP

An historical simulation for 2004 to 2014 with a 13-region, 57-commodity version of GTAP, and an application to baseline forecasting.

Set up the model with a database for 2004 and compile data on movements in observable variables from 2004 to 2014. We treat these variables as exogenous and shock them with their observed movements.

Motivation:

- To estimate trends in consumer preferences and technologies for use in baseline forecasting

Challenges:

- Compiling quantity data to supplement GTAP's value data
- Finding suitable closures

Step-by-step approach to historical simulations

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In steps 1 to 12 we introduced movements between 2004 and 2014 in each of the following:

- employment and population; *World Bank & IMF*
- real GDP; *OECD*
- nominal GDP expressed in $US converted from national currencies at the average exchange rate in 2004 and in 2014; *GTAP & OECD*
- nominal household consumption; *GTAP*
- nominal public consumption; *GTAP*
- nominal gross investment; *GTAP*
- price deflators for investment; *OECD*
- nominal imports; *GTAP*
- nominal exports; *GTAP*
- capital stocks in real terms; *Penn*
- the price indexes for oil and gas; *General authority stats, Saudi Arabia*
- fob values for selected manufacturing exports by region. *GTAP*

Results from steps 1 to 12:
Primary-factor technical change (% change 2004-14)

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	Real GDP	Employment	Capital	Real exchange rate	Primary-factor tech change		
				$P_{gdp}^{\$US}(j) / P_{gdp}^{\$US}(world)$	Total	Non-traded	Traded
						Balassa-Samuelson effect	
Country j	(1)	(2)	(3)	(4)	(5)	(6)	(7)
USA	17	3	28	-11	5	16	-13
…	…	…	…	…	…	…	…
China	160	5	212	52	66	-36	664
…	…	…	…	…	…	…	…
India	109	9	158	0	41	38	44
…	…	…	…	…	…	…	…
SaudiArabia	49	54	113	45	-15	17	-27
…	…	…	…	…	…	…	…

Shaded areas are observations

Results from steps 1 to 12:
Factor prices & rates of return (% change 2004-14)

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Falling rates of return: increase in world saving relative to investment opportunities

	Wage rate*	Rental rate*	Price of capital goods*	Rate of return
	(1)	(2)	(3)	(4)
USA	40	-4	16	-38
…	…	…	…	…
China	631	-21	73	-79
…	…	…	…	…
India	227	-53	24	-86
…	…	…	…	…
SaudiArabia	98	6	47	-35
…	…	…	…	…

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

Results from steps 1 to 12:
Expenditure components of GDP in $US[1], and import-domestic preference twists[2] (% change 2004-14)

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Rapid growth in trade relative to GDP: preference twist in favor of imports in most countries, but not all

	GDP (1)	Private cons. (2)	Public cons. (3)	Investment (4)	Exports (5)	Import (6)	Imp-Dom twist (7)
USA	41	46	38	27	81	61	-14
…	…	…	…	…	…	…	…
China	433	403	423	484	245	227	-26
…	…	…	…	…	…	…	…
India	183	188	196	217	244	318	90
…	…	…	…	…	…	…	…
SaudiArabia	191	183	205	252	203	261	41
…	…	…	…	…	…	…	…

[1] These are values in $US, converted from local currency at the average exchange rates in 2004 and in 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.

% movements between 2004 & 2014 in world prices, quantities, values and demand shifts

		Step 12 Macro only	Step13 (step 12 + com values)	Step 14 (step 13+ com quantities)	Step 15 (14+ revisions)
Price	*Paddy*	105	76	97	97
	Processed rice	71	16	198	70
Quantity	*Paddy*	57	37	22	22
	Processed rice	50	190	13	22
Value	*Paddy*	220	141	141	141
	Processed rice	156	237	237	107
Demand shift	*Paddy*	0	-42	-7	-10
	Processed rice	0	76	-20	-12

Step 13. Reduction in Paddy value (220 to 141) generates reductions in price and quantity. Quantity reduction leads to negative demand shift (-42) and reduction in price of Processed (from 71 to 16). Now increased value of Processed requires huge increase in quantity (from 50 to 190) with corresponding huge demand shift (76).

Step14. Reduction in Processed quantity (190 to 13) requires huge increase in price (16 to 198). Price increase suggests that demand shift should increase, but quantity decease suggest that demand shift should decrease. Quantity effect dominates, converting demand shift from 76 to -20.

Step 15. Introduce data on price increase for Processed (198 to 70) and revise quantity estimate for Processed to come in line with Paddy. Requires replacing GTAP value (237 to 107).

Average annual % demand shifts between 2004 and 2014: selected commodities

Plant fibres	-5.77	Paddy rice	-0.66
Wool	-6.03	Wheat	-1.67
		Other grains	-0.47
Forestry	-3.05	Vegetables &fruit	-1.34
Paper & paper prods	-0.42		
		Other food	1.23
Coal	-0.69		
Oil	0.35	Apparel	1.10
Gas	1.14	Leather	1.11
		Motor vehicles	0.92
Petroleum	-1.39	Electron equip	0.63
		Air transport	2.69
Electricity	-0.56	Electronic equip	0.63
		Financial intermediation	0.77

The GTAP historical simulation reveals worldwide preference/technology shifts:

- against 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.

Baseline forecast with and without demand-shift trends

A standard GTAP baseline relies on projections for GDP, employment and population*

We look at how adding demand-shift trends from the historical simulation affects a baseline for 2014-2017.

Baseline annual % growth from 2014 to 2017 *without* & *with* demand-shift trends, outputs for selected industries the U.S.

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		USA without	USA with			USA without	USA with
4	Vegetables &fruit	1.80	0.77	25	Other food	2.22	3.32
5	Oil seeds	3.59	4.74	26	Bev & tobac prods	2.34	3.44
7	Plant fibres	3.51	-2.51	29	Leather	0.93	1.88
8	Other crops	2.39	3.34	31	Paper & p prods	2.14	0.95
12	Wool	3.15	-8.59	32	Petroleum & coke	1.84	0.40
13	Forestry	2.57	-1.38	38	Non-ferrous metals	0.45	-0.10
15	Coal	1.96	-0.04	40	Computers &electro	0.82	1.99
16	Oil	0.40	-1.49	43	Motor vehicles	2.62	3.49
17	Gas	0.95	0.79	47	Gas distribution	1.94	0.59
20	Other meat	2.20	3.69	54	Air transport	2.07	3.96
21	Vegetable oils	1.63	4.07	65	Dwellings	2.62	3.07
22	Milk products	2.11	3.21				
23	Processed rice	2.22	0.74	GDP		2.30	2.30

GDP in both baselines grows at 2.30%

Fast growing industries (>3%) are shown in pink

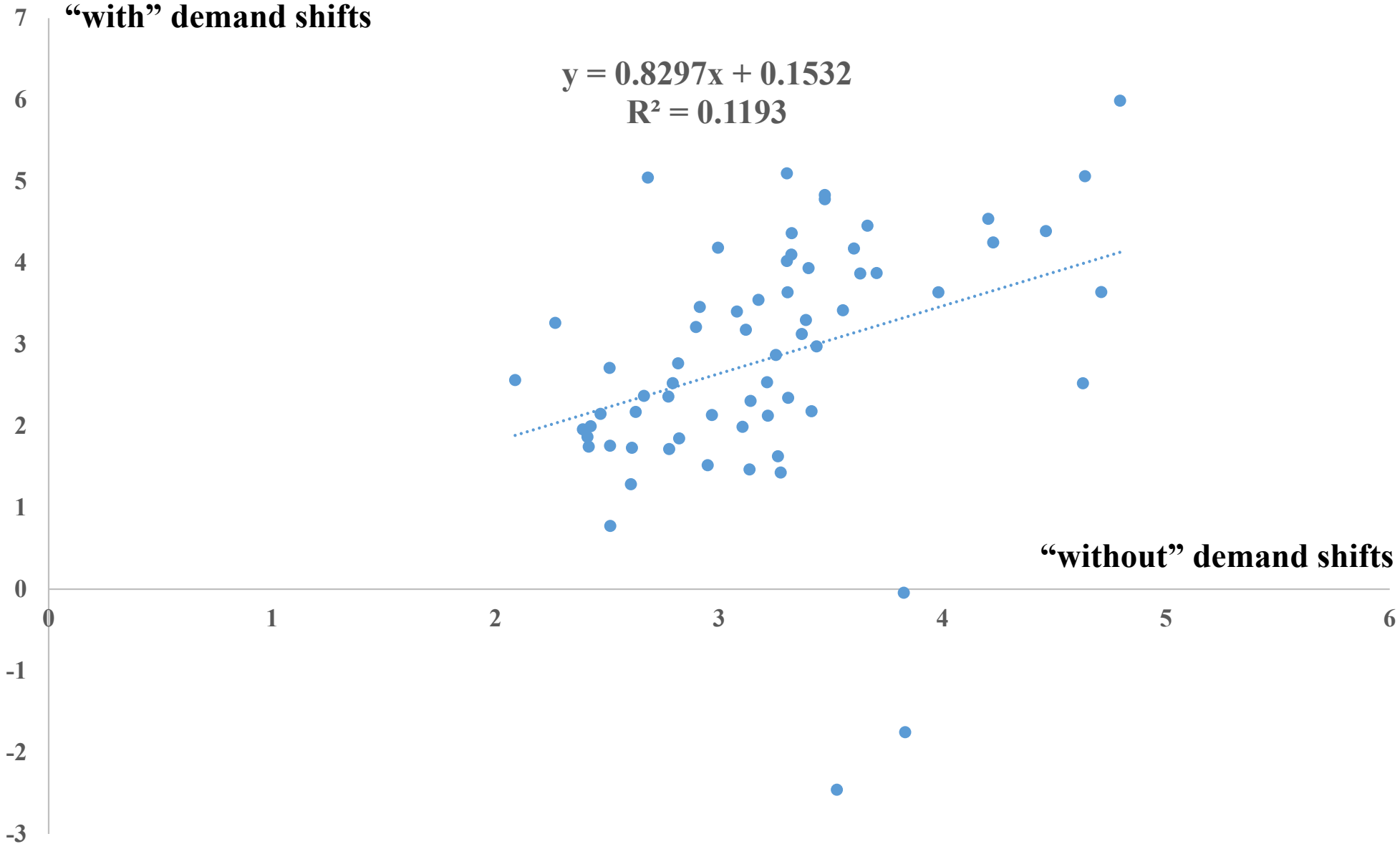
Slow growing industries (<1%) are shown in blue

Little correlation between the "without" & "with" baselines (R^2 close to zero)

"With" results are much more varied than "without"

Lack of correlation between "without" & "with" results and greater variability for "with" results holds for all regions.

% growth rates for 2014 to 2017 for world industry outputs "without" and "with" demand shifts



Concluding remarks

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There are four broad modes of analysis in dynamic CGE modelling.

- Historical
- Decomposition
- Forecast
- Policy

Historical simulations present challenges with respect to data, closures and interpretation. But they have big pay-offs.

They are valuable for updating and feed into the other three modes of analysis.