Evaluating computable models of trade

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PRELIMINARY AND IMCOMPLETE

Introduction

This paper is guided by two basic ideas:

- Predictions of trade models need to be evaluated ex-post
- Trade models need to be able to accurately predict at least some aspects of trade changes caused by trade policy changes

How do we build, use, and evaluate computable models?

Kydland (1992):

1. Formulate a question
2. Choose a model with the question in mind
3. Calibrate the model
    a. Parameter values should be calibrated on the basis of data not related to the phenomenon studied
    b. Parameter values should not be chosen to produce the best fit of the model to data being studied
4. Perform robustness check by varying parameter values within a reasonable range
5. Do a quantitative assessment of the precision with which the question has been answered
    a. Select a set of key facts to compare model results to
        - Collection of sample statistics
        - Specific events that one wants the model to replicate
    b. Select a metric to compare model outcomes to data

What are the evaluation criteria?

Computable models are evaluated in order to answer one or more of the following questions (Canova and Ortega, 2000):

- Is it possible to generate *Z* using theory *W*?
- How much of the fact *X* can be explained with shocks of type *Y*?
- Is it possible to reduce the discrepancy *D* of the theory from the data by introducing feature *F* in the model?

Important to remember:

- All models are approximations
- Therefore, they are all false
- Modify Leamer's “estimate, not test” to “evaluate, not test”

Specific features of computable trade models

- They typically have many parameters
  - e.g. preferences, technology, trade costs
- They have a nearly perfect fit with the data used to parametrize them
- Evaluating model fit in this case is not indicative of the quality of the model
- Instead, it is useful to take the models outside the time interval used to parametrize them

This paper asks: how does trade change in response to trade liberalization?

- Models
  - GTAP model
  - Brown-Deardorff-Stern (BDS) model
  - Model with heterogeneous producers based on the Eaton-Kortum model
- All models are
  - General equilibrium (can account for trade diversion, factor reallocation across industries, industry linkages, and price changes)
  - Designed to explain trade flows
  - Well suited to predicting the effects of trade policy changes on trade
- In order to perform quantitative assessment, we need:
  - Key facts to evaluate the models
  - Metric to compare model predictions to data

Data – CUSFTA and NAFTA

- NAFTA is a big historical experiment that can be used to evaluate the performance of trade models
- CUSFTA goes into effect in 1989, NAFTA in 1994
- Gradual removal of policy-related trade barriers
- Average phase-out periods in NAFTA: 1.4 years for U.S., 5.6 years for Mexico (Kowalczyk and Davis, 1996)
- Maximum phase-out period was 10 years

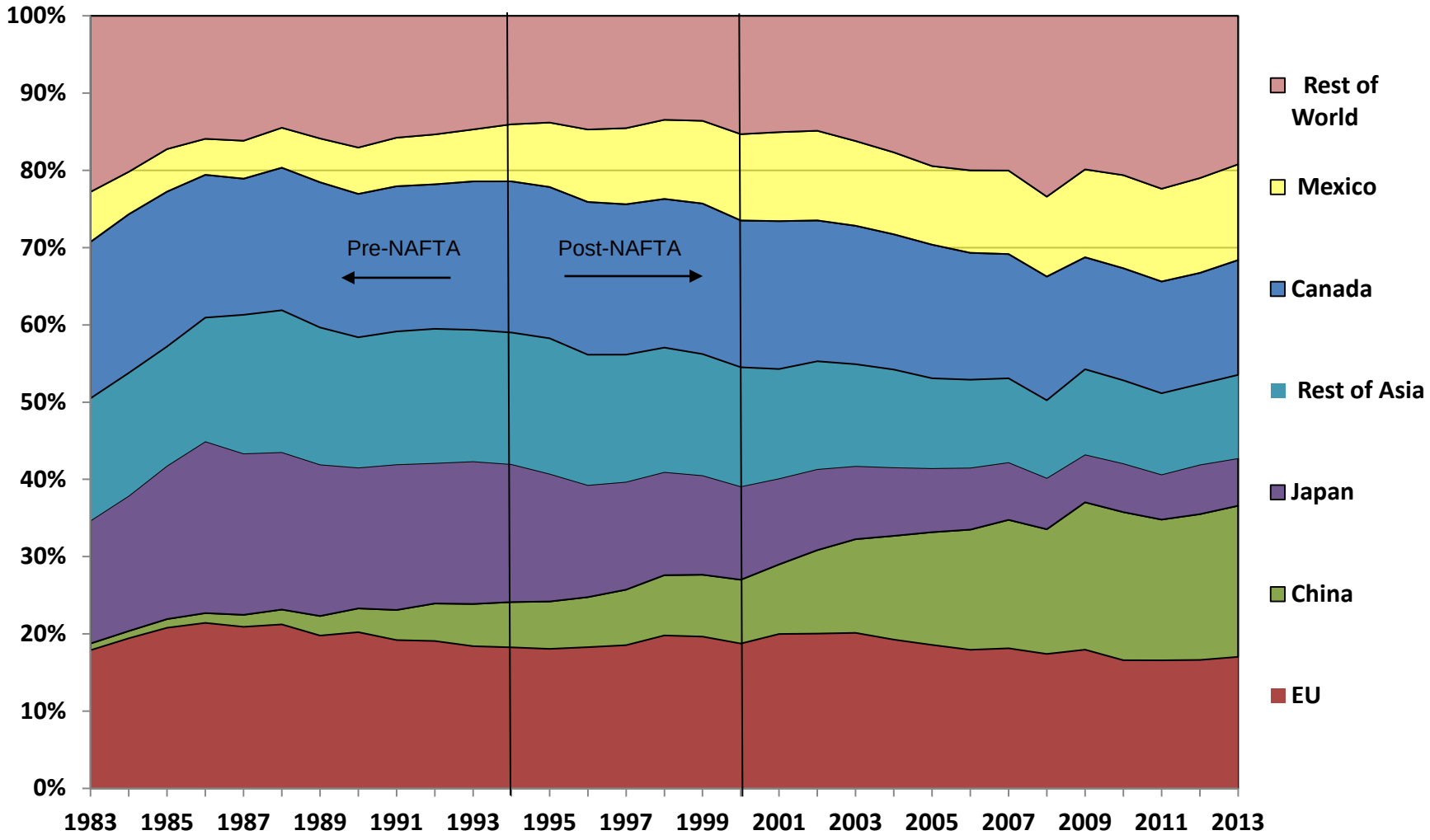
CUSFTA and NAFTA

- NAFTA had a significant effect on trade between its members and a small-to-moderate effect on their incomes and employment (Burfisher, Robinson, and Thierfelder, 2001; Anderson and van Wincoop, 2002; Romalis, 2007, many other papers)

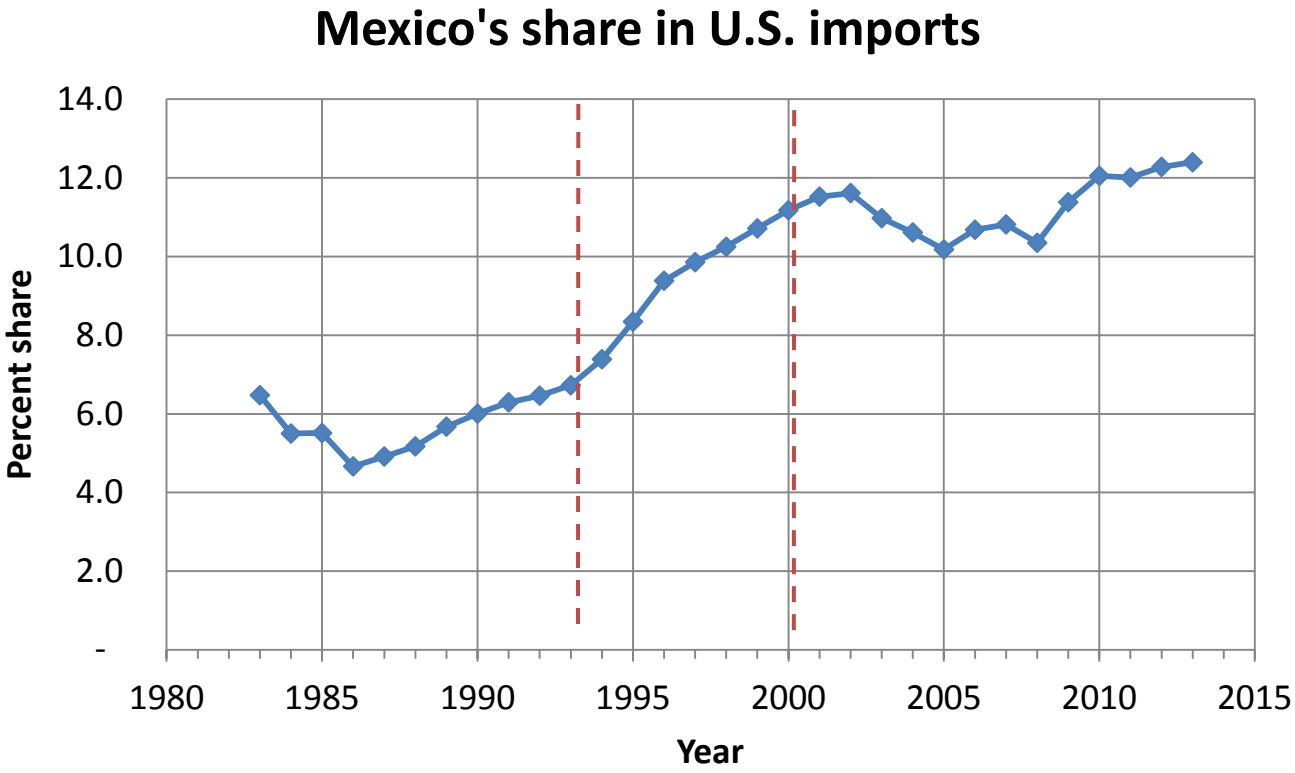
Between 1993 and 2000:

- Total NAFTA trade relative to the total NAFTA GDP grew 57%
- Fraction of U.S. income that was spent on Mexican goods grew 128%
- Fraction of Mexican goods in total Canadian imports went up 61%

U.S. Merchandise Import Shares by Country and Region, 1983-2013



The figure is from De La Cruz and Riker (2014) using data from the U.S. Department of Commerce.



Year	Import share
1983	6.5%
1993	6.7%
2000	11.2%
2008	10.3%

Import shares compiled by De La Cruz, J. and Riker, D. (2014) using U.S. Department of Commerce data.

Computable general equilibrium (CGE) models were extensively used to analyze NAFTA

- Quantitative economic analysis was extensively used in the early 1990s to predict the effects of NAFTA
- Their predictions pointed to little effect on trade, output, and employment in the U.S., and moderate effects on Mexico
- Pre-NAFTA models did not do well
- There were two problems with pre-NAFTA economic predictions (Kehoe, 2005):
  - CGE models significantly underpredicted the effect of NAFTA on trade, across all industries
  - Forecasted industry-level changes in bilateral trade have little correlation with the actual post-NAFTA industry-level changes

Literature (continued)

Pre-NAFTA predictions of the effects of NAFTA (originally published in 1992, then republished in 1994, 1995):

- Brown, Deardorff, and Stern (BDS): IRS, removes tariffs and NTBs, allows FDI into Mexico
- Cox and Harris: IRS, removes tariffs and NTBs
- Sobarzo: IRS, removes tariffs, allows FDI into Mexico
- Roland-Holst-Reinert-Shiells (RRS): CRS and IRS, tariffs only and tariffs+NTBs

GTAP model

- Appeared in the early 1990s
- Was not used in pre-NAFTA simulations of the effects of NAFTA
- Is now used widely around the world
- Has been used in many USITC studies

Brown-Deardoff-Stern model

- Also known as the Michigan model
- Originally developed in the mid 1970s by Alan Deardorff and Robert Stern
- Drusilla Brown joined the project in 1980s
- Since 1980s the model incorporates monopolistic competition
- The model has been used to study the effects of the Tokyo Round, effects of exchange rate changes, the structure of protection, trade liberalization leading up to the Uruguay Round, US-Canada Free Trade Agreement, and NAFTA

Heterogeneous producers model

- Appeared in the late 1990s - early 2000s
- Founded on new firm-level evidence
- The Eaton-Kortum (2002) model is one of the most popular heterogeneous producer models
- A Ricardian model extended to many goods and countries
- The Eaton-Kortum methodology was inserted into a multi-industry model with cross-industry linkages by Shikher (2004)
- We call it the HPPC model (heterogeneous producers, perfect competition)

Similarities between model

- Multiple industries
- Intra-industry linkages modeled by the input-output table
- Two factors of production: capital and labor
- Fixed factor endowments in each country
- Factors are mobile across industries

The resulting equations are similar

- CES form for choice across domestic and international suppliers
- Factor and good markets clearing conditions are similar

Differences across models

- Modeling of intra-industry trade
  - GTAP and BDS use the Armington assumption while the HPPC model uses EK methodology
- Interpretation of parameters is different
  - GTAP and BDS: preference parameters
  - HPPC: trade costs and productivity differences
- Market structure
  - GTAP and HPPC have perfect competition
  - BDS has monopolistic competition in the manufacturing industries
- Solutions methods
  - HPPC is solved as a non-linear system
  - GTAP is coded in linerarized equations and the software (GEMPACK) approximates a solution to the underlying non-linear system
  - BDS is linearized

Parametrization

GTAP

- Latest version of the GTAP model
- Version 3 (1992) of the GTAP database
- 8 manufacturing industries as well as nonmanufacturing industries
- 5 "countries": Canada, Mexico, USA, EU12, and ROW

HPPC

- 1989 data
- 8 manufacturing industries and 19 OECD countries

BDS

- 1989 data
- 29 industries (of which 23 are tradable)
- 8 countries

Simulations

- Remove tariffs and tariff equivalents of NTBs between NAFTA countries
- Only trade in manufacturing industries is liberalized; other industries in GTAP and BDS models are left as is
- Same amount of protection is removed in GTAP and HPPC models
- Tariffs and NTB tariff equivalents are from Nicita and Olarreaga's Trade, Production, and Protection Database (2007)
- BDS model has its own estimates of protection

Simulations

- We performed 4 versions of GTAP simulations:
  - with standard GTAP elasticities (between 2 and 7)
  - with all elasticities set to 8 (both domestic/import and import sources substitution elasticities)
  - with all elasticities set to 3 (as in the BDS model)
  - with standard GTAP elasticities and Johansen solution method

Evaluation of predictions

- We will look at:
  - Changes in import shares (shares of country *i* in country *n*'s imports of industry *j*)
  - Changes in NAFTA trade (relative to total trade or GDP)
- We will compare model predictions to the actual changes during 1989-2000 and 1989-2008
- Comparison metrics (following Kehoe (2005)):
  - Correlation between predicted and actual data
  - Intercept and slope from the regression of actual on predicted
  - Note: R^2 for this regression is correlation squared

Events other than NAFTA

Events outside the model that may have affected the post-NAFTA trade:

1. Peso devaluation
   - Affects all industries
   - The effect most likely dissipated by 2008
2. Rise of China
   - Continued after 2000
   - Chinese import share in the U.S. increased mostly at the expense of Japanese and other Asian countries' import shares
   - We observe an increase in the share of Mexican imports in the U.S. during the 1990s

Events other than NAFTA

3. Segmentation of production
   - Affected all countries
4. Technological growth
   - Affects both trade and GDP
   - By most estimates, technological change in Mexico was not much greater than in the U.S.
   - Differential (across industries) technological growth is possible

Priors

- Simulation results from GTAP and HPPC can be similar because
  - There are many similarities between GTAP and HPPC model equations
- Simulation results can be different because
  - Equations are not identical
  - BDS has a different type of market structure
  - Implementation and solution methods are different
  - Previous Armington-based models did not do well in predicting the effects of NAFTA

Policy-related trade barriers removed by NAFTA

Tariffs

Country	Food	Textile	Wood	Paper	Chemicals	Nonmetals	Metals	Machinery	Manuf.
Canada	8.83	17.65	8.48	3.46	8.26	7.78	4.83	5.63	8.51
Mexico	15.93	17.48	15.02	5.84	12.35	15.26	9.86	13.74	13.71
United States	2.14	10.64	2.47	0.62	4.48	7.43	3.04	3.37	4.68

Tariff equivalents of non-tariff barriers

Canada	3.23	7.95	12.96	0.00	1.23	0.00	11.82	0.87	3.33
Mexico	26.68	22.89	8.39	11.12	17.09	18.11	4.03	19.21	17.70
United States	11.07	5.81	2.63	0.67	3.28	0.51	0.00	4.05	4.10

Total policy-related trade protection

Canada	12.06	25.60	21.44	3.46	9.49	7.78	16.65	6.50	11.84
Mexico	42.61	40.37	23.41	16.96	29.44	33.37	13.89	32.95	31.42
United States	13.21	16.45	5.10	1.29	7.76	7.94	3.04	7.42	8.78

Productivities in the HPPC model relative to the United States

	Food	Textile	Wood	Paper	Chemicals	Nonmet.	Metals	Machinery
Canada	0.852	0.862	0.920	0.966	0.797	0.788	0.989	0.795
Mexico	0.571	0.564	0.422	0.447	0.609	0.570	0.629	0.500
U.S.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Australia	0.847	0.755	0.614	0.677	0.693	0.688	0.897	0.702
Austria	0.646	0.798	0.651	0.745	0.717	0.824	0.786	0.728
Finland	0.590	0.737	0.746	0.904	0.706	0.693	0.841	0.728
France	0.886	0.958	0.787	0.850	0.887	0.972	0.938	0.871
Germany	0.831	0.954	0.833	0.875	0.925	0.989	0.955	0.924
Greece	0.684	0.687	0.449	0.494	0.560	0.663	0.679	0.477
Italy	0.812	1.045	0.878	0.826	0.846	1.040	0.887	0.883
Japan	0.738	0.970	0.773	0.868	0.935	1.049	1.001	1.025
Korea	0.660	0.871	0.559	0.612	0.724	0.683	0.794	0.713
New Zeal.	0.883	0.709	0.625	0.682	0.658	0.567	0.706	0.603
Norway	0.758	0.660	0.656	0.776	0.741	0.670	0.869	0.701
Portugal	0.616	0.648	0.507	0.580	0.538	0.636	0.580	0.509
Spain	0.771	0.788	0.645	0.709	0.737	0.829	0.820	0.693
Sweden	0.662	0.721	0.733	0.848	0.746	0.750	0.845	0.785
Turkey	0.595	0.621	0.392	0.374	0.548	0.604	0.648	0.429
U.K.	0.838	0.871	0.704	0.805	0.848	0.878	0.881	0.822

Actual vs. predicted percent changes in trade

Measure	Actual 1989-2008	Predicted HPPC	Predicted GTAP(std)
NAFTA trade relative to the total trade of the NAFTA countries	24.8	25.9	28.7
NAFTA trade relative to the total income of the NAFTA countries	66.5	62.2	

Note: NAFTA trade is the sum of all bilateral trade flows between the NAFTA countries. The total trade of the NAFTA countries is the sum of their exports and imports. The total income of the NAFTA countries is the sum of their GDPs.

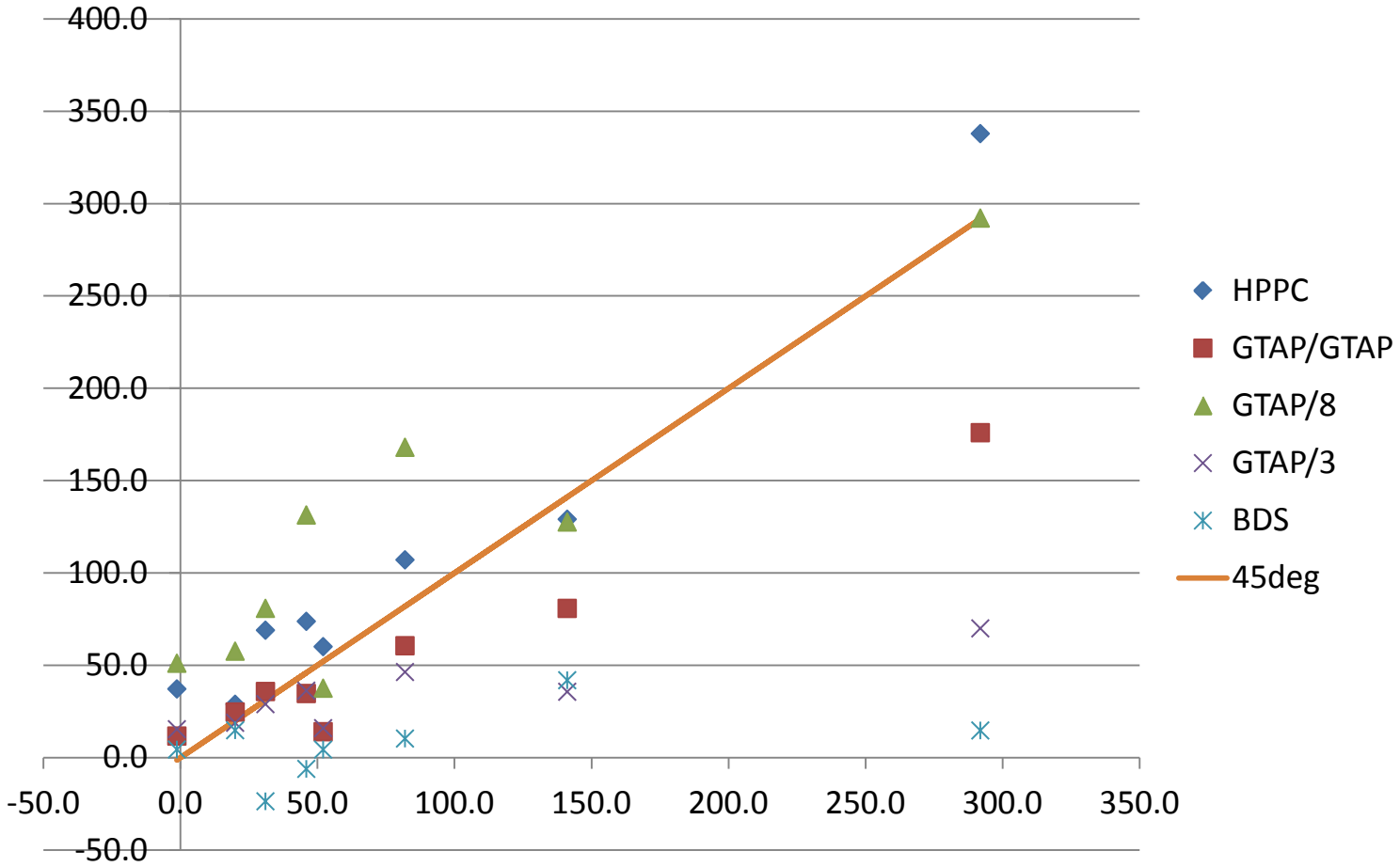
	Actual	Predicted		
Variable	1989–2008	HPPC	GTAP(std)	BDS
Canadian exports	66.7	45.4	23.6	4.3
Canadian imports	58.2	37.1	16.9	4.2
Mexican exports	120.3	130.4	79.4	50.8
Mexican imports	64.2	58.3	42.2	34.0
U.S. exports	39.2	24.0	11.0	2.9
U.S. imports	46.2	17.5	7.7	2.3
Correlation with data		0.98	0.95	0.86

Note: Exports and imports are measured relative to GDP. The Brown-Deardorff-Stern (BDS) model has increasing returns to scale. The model with heterogeneous producers (HPPC) described in this paper has constant returns to scale. GTAP results are not relative to GDP (though GDP changes are very small relative to trade changes).

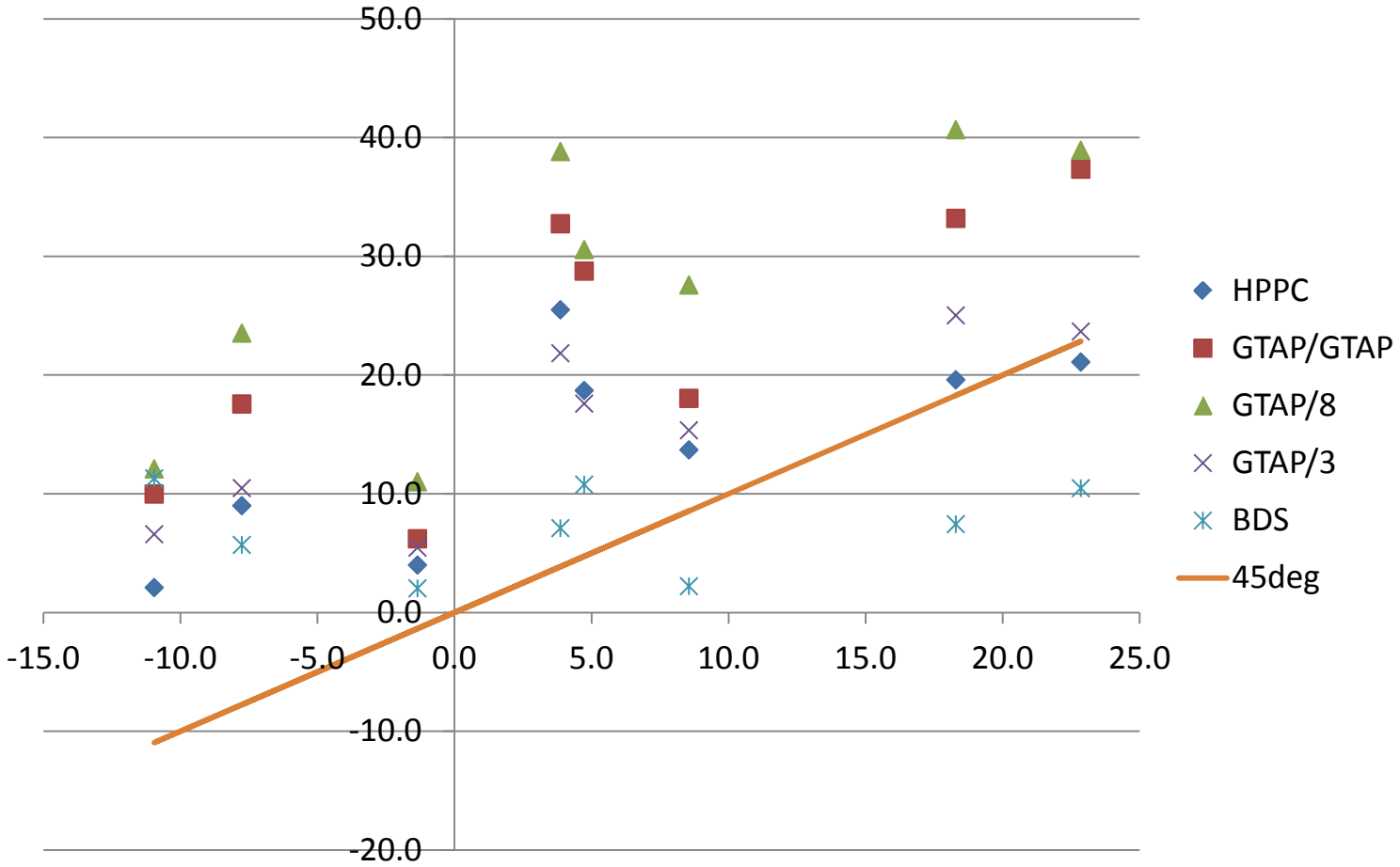
Actual percent changes in import shares, 1989-2008

Importer	Exporter	Food	Textile	Wood	Paper	Chemicals	Nonmetals	Metals	Machinery
Canada	Mexico	92.71	202.83	1580.50	185.78	413.43	208.89	-59.72	254.06
Canada	U.S.	36.15	72.85	16.11	8.95	14.56	25.98	6.83	2.82
Mexico	Canada	20.83	-65.01	846.37	-40.81	5.36	-68.86	-70.19	-35.60
Mexico	U.S.	18.29	22.85	-10.96	-1.35	8.55	3.86	-7.76	4.73
U.S.	Canada	73.45	93.67	-4.37	-11.19	5.78	17.65	-9.06	-5.69
U.S.	Mexico	81.93	291.84	52.06	-1.31	45.92	31.01	19.95	141.12

Predicted vs. actual U.S. imports from Mexico (each point represents an industry)



Predicted vs. actual U.S. export to Mexico (each point represents an industry)



Actual(1989-2008) vs. predicted changes

		HPPC model			BDS model			GTAP(std) model		
Importer	Exporter	Correlation	Intercept	Slope	Correlation	Intercept	Slope	Correlation	Intercept	Slope
Canada	Mexico	-0.15	423.10	-1.31	0.41	111.09	23.89	-0.23	458.71	-2.51
Canada	U.S.	0.91	5.71	1.04	0.95	5.54	2.88	0.90	9.69	0.51
Mexico	Canada	-0.57	-185.64	-12.53	-0.14	93.82	-0.81	-0.49	295.40	-13.58
Mexico	U.S.	0.72	-9.46	1.00	0.10	2.54	0.31	0.78	-13.37	0.79
U.S.	Canada	0.77	-7.59	0.81	0.28	12.26	0.58	0.86	-4.69	0.76
U.S.	Mexico	0.98	-15.70	0.93	0.44	65.84	2.23	0.98	-11.24	1.72

		GTAP(8) model			GTAP(3) model			GTAP(std,Joh) model		
Importer	Exporter	Correlation	Intercept	Slope	Correlation	Intercept	Slope	Correlation	Intercept	Slope
Canada	Mexico	-0.29	558.96	-2.28	-0.20	520.72	-5.65	-0.22	473.98	-4.44
Canada	U.S.	0.92	7.47	0.47	0.92	5.96	1.27	0.90	7.12	0.81
Mexico	Canada	-0.47	336.41	-10.99	-0.46	351.60	-18.57	-0.45	284.69	-11.31
Mexico	U.S.	0.79	-17.41	0.80	0.85	-15.92	1.31	0.75	-11.90	0.73
U.S.	Canada	0.91	-10.79	0.60	0.93	-19.25	2.29	0.88	-12.13	1.40
U.S.	Mexico	0.90	-38.32	1.02	0.89	-69.73	4.56	0.97	-37.87	3.46

Correlations between actual and predicted industry-level bilateral trade flows, except those between Canada and Mexico (32 trade flows in total)

HTTP	0.95
GTAP (std)	0.86
GTAP (8)	0.90
GTAP (3)	0.83
GTAP (std,Joh)	0.79
BDS	0.31

Results

- The GTAP model with standard elasticities underpredicts changes in U.S. imports from Mexico and overpredicts changes in U.S.-Canada trade and U.S. exports to Mexico
- The GTAP model with elasticities set to 8 does a good job predicting changes in U.S. imports from Mexico, but significantly overpredicts changes in U.S.-Canada trade and U.S. exports to Mexico
- The correlation of predicted and actual changes across industries for the GTAP model is a little less than for the HPPC model, but much higher than for the BDS model. This was one of the key criticisms of Kehoe (2005).
- None of the models are able to predict changes in Canada-Mexico trade

Results (continued)

- The overall conclusion so far is that the GTAP model performs much better than the BDS model, but less well than the HPPC model
- We need to investigate why GTAP and HPPC make different predictions and why BDS and GTAP make different predictions. We also need to investigate why all models fail to correctly predict Canada-Mexico trade.