

Bridging the gap between CGE and NQT

CoPS

by

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This year's distinguished speakers include: **Thomas Hertel** (Purdue University), **Ashely Winston** (MacroDyn Group), **Peter Dixon** (Victoria University), **Maureen Rimmer** (Victoria University), **Samuel Kortum** (Yale University, co-organizer), **Lorenzo Caliendo** (Yale University), **Costas Arkolakis** (Yale University, co-organizer), **Joseph Francois** (Universität Bern), **Eddy Bekkers** (WTO), and **Robert Koopman** (American University, co-organizer), **Anton Yang** (American University, co-organizer)

Peter Dixon and I were tasked with:

- (a) providing the NQT people with a brief history of CGE**
- (b) providing a bridge to NQT**
 - we did this by coding and running the Eaton and Kortum (2002) model in GEMPACK**

Bridging the gap between CGE and NQT

Plan of presentation



- (1) Worldwide use of CGE and GTAP**
- (2) 3 giants on the path to GTAP, what did they do?**
- (3) How does NQT work: micro foundations**
- (4) Why do EatonKortum (2002) results look like Armington results?**
- (5) Conclusions**

(1) the worldwide use of CGE and GTAP

- **Leif Johansen**, 1960, first CGE model
- CGE takes off as a policy tool in Australia from the mid 1970s: **Peter Dixon**
- Worldwide blossoming of CGE from the mid 1990s with the creation by **Tom Hertel** of GTAP. By 2025 there were 33,000 in the GTAP community.
- 3 factors explain the endurance and acceleration of CGE
 - (1) *right tool for many issues*
 - (2) *Tom Hertel and GTAP from 1992*
 - (3) *Democratizing software: GEMPACK and GAMS*

(2) the path to GTAP: Lief Johansen

Johansen (1960) is one of those rare books that is a complete break with previous literature. He documents the first CGE model, a 22 industry of Norway

Johansen had 132 variables and 86 equation, his model was presented in percentage changes, and changes.

- He was obsessed with interpretations of his T matrix of elasticities of endogenous variables with respect to exogenous variables (86x46 matrix).
- He emphasized explaining results via simple 1-industry BOTE models

But

- His model had 2 problems:
 - (i) linearization errors (1-step solution)
 - (ii) perfect substitution between domestic and imported goods.
This led to crippling problem: extreme specialization (flip-flop).
[To overcome this specialization problem *ad hoc* constraints on imports and exports were introduced.]

(2) the path to GTAP: Peter Dixon

In 1975, at the IMPACT Project under the direction of Alan Powell, Peter Dixon was tasked with building a detailed industry model of Australia with a specific policy question in mind: where would the jobs come from if Australia slashed its crippling high tariffs?

Dixon brought two influences to this assignment. Armington and Leontief.

Armington (1969) introduced imperfect import-domestic substitution in a 1-commodity 15-country model. Peter integrated Armington's specification into Leontief's I-O model: the result was the 100-industry ORANI model (Dixon *et al.* 1977 & 1982) without the flip-flop and linearization errors that had beset earlier trade models.

ORANI contained many other major long-lasting innovations:

- flexible closures;
- technical changes and indirect taxes associated with every input-output flow;
- explicit modelling of transport, wholesale and retail margins;
- a regional dimension; and
- rich functional forms e.g. CRESH and CRETH.

Like Johansen 17 years earlier, Dixon used a percentage change approach and had a passion for explaining his results via back-of-the-envelope models.

(2) the path to GTAP: Tom Hertel

The conduit from the Johansen-style modelling in Australia to the rest of the world is GTAP founded in 1992 by Tom Hertel at Purdue.

Hertel visited the IMPACT Project in Australia for the academic year 1990-1991.

During his visit he was introduced to the ORANI model and the GEMPACK software.

He was particularly impressed with the SALTER model: a Johansen-style multi-country model being constructed at the Industries Assistance Commission in Canberra (IMPACT's main government sponsoring agency) using ORANI as the theoretical starting point and GEMPACK software.

Hertel took SALTER back to Purdue and this formed the basis of the first version of GTAP.

GTAP is extraordinarily successful. It was purpose built for the proliferation of the bi-lateral and multi-lateral trade policies of the 1990s.

On institutional arrangement Hertel(1994) explains that GTAP “ was established ... on the institutional principles of the IMPACT project ...”. Reflecting Alan Powell's approach at IMPACT, Hertel emphasized transferability of data and model code, replicability or results and openness supported by training courses and documentation.

Hertel's financing strategy was to set up a consortium of interested agencies. Hertel's particular forte has been to organize major inputs in-kind to GTAP. He has indeed created a thriving community.

(3) how does NQT work: micro foundations for EK(2002)

EK's model is Ricardian: variety j from country i is a perfect substitute for j from any other country.

Key EK ideas: (a) there are a continuum of varieties and (b) the productivity of variety j in country i is drawn from a probability distribution

The price at which country i can offer variety j to country n is given by

$$P_{in}(j) = \frac{C_i}{Z_i(j)} * D_{in} \quad (3.2)$$

where $Z_i(j)$ is i 's productivity in the production of j .

Country n satisfies its needs for variety j by sourcing from the country that can deliver j at the lowest price.

EK assume that productivity for each variety in country i is drawn from a Fréchet distribution

$$F_i(z) = \exp(-T_i z^{-\theta}) \quad (3.3)$$

where $F_i(z)$ is the probability for any variety in country i of having a productivity of $< z$

and T_i and θ are positive parameters.

(3) how does NQT work: EK(2002) solved in GEMPPACK

		1. Levels	2. Deviation version suitable for GEMPACK
(4)	Share of country i in total sales of goods in n	$\Pi_{in} = \frac{V_{in}}{V_n}$	$\pi_{in} = v_{in} - v_n$
(12)	i's value share in n's market as a function of productivity, cost and distance variables	$\Pi_{in} = \frac{T_i C_i^{-\theta} D_{in}^{-\theta}}{\sum_s T_s C_s^{-\theta} D_{sn}^{-\theta}}$	$\pi_{in} = t_i - \theta * c_i - \theta * d_{in} - \sum_s \Pi_{sn} * [t_s - \theta * c_s - \theta * d_{sn}]$
(14)	Price level in country n	$P_n = \gamma * \left[\sum_{i=1}^N T_i [C_i * D_{in}]^{-\theta} \right]^{-1/\theta}$	$p_n = \frac{-1}{\theta} * \sum_i \Pi_{in} * (t_i - \theta * c_i - \theta * d_{in})$

Cumulative distribution of productivities in i $F_i(T_i, \theta, z) = \exp(-T_i z^{-\theta})$

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(3) how does NQT work: EK illustrative sims (%deviation)

	U.S. tariff, no retaliation	U.S. tariff, with retaliation
Tariffs, US	30	30
Tariffs, against US	0	30
Welfare		
USA	0.31	-0.54
Canada	-1.54	-1.76
Mexico	-2.10	-2.39
..	..	..
China	-0.35	-0.37
Real wage		
USA	-1.22	-1.58
Canada	-1.50	-1.90
Mexico	-1.87	-2.37
..	..	..
China	-0.20	-0.26

Bekkers et al. (2023) and our illustrative EK application produce results that look like those that could be obtained from an Armington model.

(4) Why do EK(2002) results look like Armington results?

Here are EK equations in percentage change forms

$$(4) \quad v_{in} - v_n = \pi_{in}$$

$$(12) \quad \pi_{in} = t_i - \theta * c_i - \theta * d_{in} - \sum_s \Pi_{sn} * [t_s - \theta * c_s - \theta * d_{sn}]$$

$$(14) \quad p_n = \frac{-1}{\theta} * \sum_i \Pi_{in} * (t_i - \theta * c_i - \theta * d_{in})$$

Define quantities as values less prices

$$(a) \quad q_{in} = v_{in} - p_{in}$$

$$(b) \quad q_n = v_n - p_n$$

Show that the price of the bundle of varieties that goes from i to n is given by

$$(c) \quad p_{in} = c_i + d_{in} - \frac{t_i}{\theta}$$

Using (4), (12) and (14) together with definitions (a) to (c) we can derive the Armington equation:

$$q_{in} = q_n - (1 + \theta) * (p_{in} - p_n)$$

..... EK(2002) is equivalent to Armington

Concluding remarks on EK and CGE

In early CGE models, good j produced in country n is a perfect substitute for good j produced anywhere else. This led to the problem of **extreme specialization**: import shares flipping between 0 and 1 and a country's exports being far too specialized.

Armington solved the specialization problem. Any broadly defined commodity j produced in one country can be modelled in the Armington style as an **imperfect substitute** for commodity j produced in another country. With the adoption of the Armington specification, a CGE model can produce realistic responses of trade shares to policy and other shocks.

EK imagine going to fine commodity classifications where there are no differences in the characteristics of commodities in the same classification but produced in different countries. Yet, EK produce a trade specification in which trade shares behave in an empirically reasonable manner. If costs rise in country n in a broadly defined industry j , then in the background to an EK model, country n loses its exports in some of the narrowly defined subcategories of j . This is not explicit in an EK-style CGE model. It shows up as a loss by n of a fraction of its exports of broadly defined commodity j . **EK results not only look like Armington results, they are exactly equivalent to Armington results.**

EK have contributed an attractive micro-economic story that justifies the Armington specification applied for commodities defined at statistically relevant levels of disaggregation. EK's dispersion parameter θ plays a similar role to Armington's import-domestic substitution elasticity.

The END

GEMPACK beats GAMS in 2013

CoPS



Horridge & Pearson

Since 2013 GEMPACK times have come down by 70%

Speed makes it possible to do more ambitious projects



Meeraus & Rutherford

