Recent Developments in Trade Theory and Empirics

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Outline:

1. Standard theory (hybrid Heckscher-Ohlin/New Trade Theory) does not well when matched with the data on the growth and composition of trade.

2. Applied general equilibrium models that put the standard theory to work do not well in predicting the impact of trade liberalization experiences like NAFTA.

3. Much of the growth of trade after a trade liberalization experience is growth on the extensive margin. Models need to allow for corner solutions or fixed costs.

4. Fixed costs seem better than Ricardian corner solutions for reconciling time series data on real exchange rate fluctuations with data on trade growth after liberalization experiences.

5. Growth theory needs to be reconsidered in the light of trade theory. In particular, a growth model that includes trade can have the opposite convergence properties from a model of closed economies.

6. Favorable changes in the terms of trade and/or reductions tariffs make it easier to import intermediate goods. Although this is often interpreted as an increase in productivity, it does not show up as such in productivity measures that use real GDP as a measure of output.

7. In models with heterogeneous firms (for example, Melitz, Chaney), trade liberalization can cause resources to shift from less productive firms to more productive firms. Although this is often interpreted as an increase in productivity, it does not show up as such in productivity measures that use real GDP as a measure of output.

TRADE THEORY AND TRADE FACTS

- Some recent trade facts
- A “New Trade Theory” model
- Accounting for the facts
- Intermediate goods?
- Policy?

How important is the quantitative failure of the New Trade Theory?

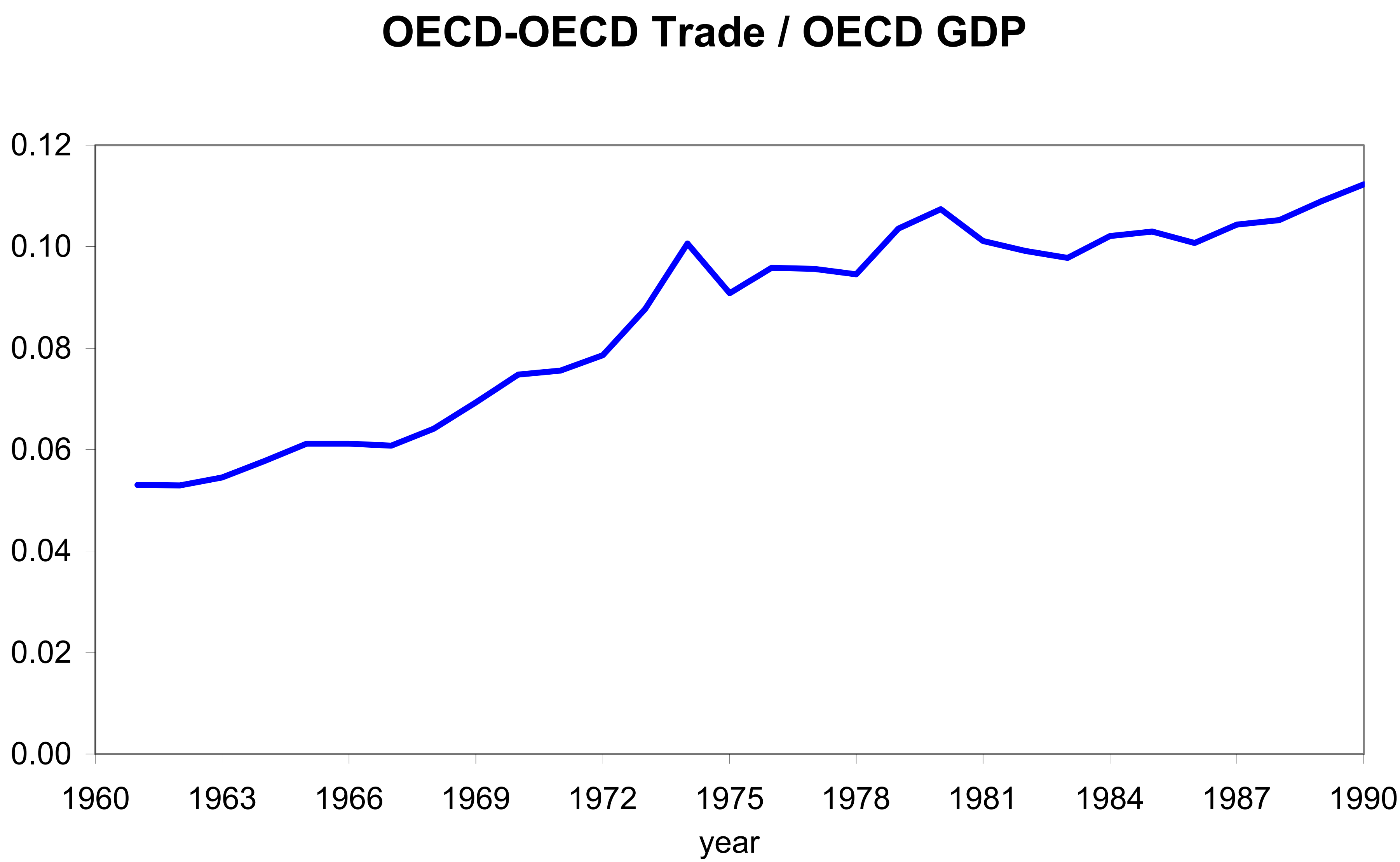
Where should trade theory and applications go from here?

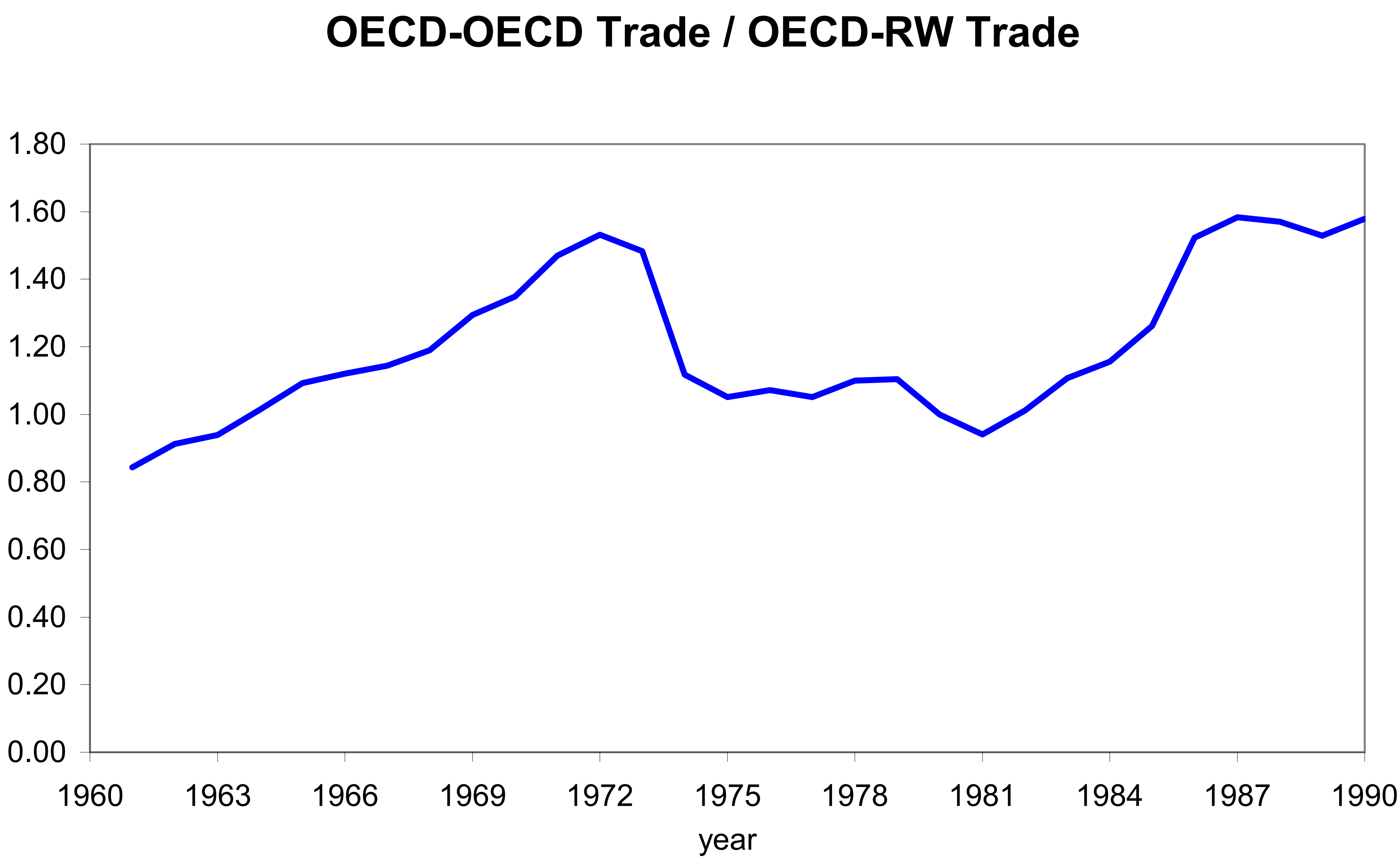
SOME RECENT TRADE FACTS

- **The ratio of trade to product has increased.**
  World trade/world GDP increased by 59.3 percent 1961-1990.
  OECD-OECD trade/OECD GDP increased by 111.5 percent 1961-1990.

- **Trade has become more concentrated among industrialized countries**
  OECD-OECD trade/OECD-RW trade increased by 87.1 percent 1961-1990.

- **Trade among industrialized countries is mostly intraindustry trade**
  Grubel-Lloyd index for OECD-OECD trade in 1990 is 68.4.
  Grubel-Lloyd index for OECD-RW trade in 1990 is 38.1.


OECD-OECD Trade / OECD GDP
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
year



OECD-OECD Trade / OECD-RW Trade
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
year

Helpman and Krugman (1985):

"These....empirical weaknesses of conventional trade theory...become understandable once economies of scale and imperfect competition are introduced into our analysis."

Markusen, Melvin, Kaempfer, and Maskus (1995):

"Thus, nonhomogeneous demand leads to a decrease in North-South trade and to an increase in intraindustry trade among the northern industrialized countries. These are the stylized facts that were to be explained."

Goal: To measure how much of the increase in the ratio of trade to output in the OECD and of the concentration of world trade among OECD countries can be accounted for by the "New Trade Theory."

PUNCHLINE

In a calibrated general equilibrium model, the New Trade Theory cannot account for the increase in the ratio of trade to output in the OECD.

Back-of-the-envelope calculations:

Suppose that the world consists of the OECD and the only trade is manufactures.

With Dixit-Stiglitz preferences, country j exports all of its production of manufactures Y_m^j except for the fraction $s^j = Y^j / Y^{oe}$ that it retains for domestic consumption.

World imports:

$$M = \sum_{j=1}^{n} \left(1 - s^j\right) Y_m^j .$$

World trade/GDP:

$$\frac{M}{Y^{oe}} = \frac{M}{Y_m^{oe}} \frac{Y_m^{oe}}{Y^{oe}} = \left(1 - \sum_{j=1}^{n} (s^j)^2\right) \frac{Y_m^{oe}}{Y^{oe}} .$$

World trade/GDP:

$$\frac{M}{Y^{oe}} = \frac{M}{Y_m^{oe}} \frac{Y_m^{oe}}{Y^{oe}} = \left(1 - \sum_{j=1}^{n} (s^j)^2\right) \frac{Y_m^{oe}}{Y^{oe}}.$$

$\left(1 - \sum_{j=1}^{n} (s^j)^2\right)$ goes from 0.663 in 1961 to 0.827 in 1990.

Y_m^{oe} / Y^{oe} goes from 0.295 in 1961 to 0.222 in 1990.

$$0.663 \times 0.295 = 0.196 \approx 0.184 = 0.827 \times 0.222.$$

Effects cancel!

A "NEW TRADE THEORY" MODEL

Environment:

- Static: endowments of factors are exogenous
- 2 regions: OECD and rest of world
- 2 traded goods: homogeneous — primaries (CRS) and differentiated — manufactures (IRS)
- 1 nontraded good — services (CRS)
- 2 factors: (effective) labor and capital
- Identical technologies and preferences (love for variety) across regions
- Primaries are inferior to manufactures

We only consider merchandise trade in both the data and in the model.

Key Features of the Model

Consumers' problem:

$$\max \quad \frac{\beta_p (c_p^j + \gamma_p)^\eta + \beta_m \left(\int_{D^w} c_m^j(z)^\rho \, dz_p \right)^{\eta/\rho} + \beta_s (c_s^j + \gamma_s)^\eta - 1}{\eta}$$

$$\text{s.t.} \quad q_p c_p^j + \int_{D^w} q_m(z) c_m^j(z) dz_p + q_s^j c_s^j \leq r^j k^j + w^j h^j .$$

Firms' problems

Primaries and Services: Standard CRS problems.

$$Y_p^j = \theta_p (K_p^j)^{\alpha_p} (H_p^j)^{1-\alpha_p}$$

$$Y_s^j = \theta_s (K_s^j)^{\alpha_s} (H_s^j)^{1-\alpha_s}$$

Manufactures: Standard (Dixit-Stiglitz) monopolistically competitive problem:

- Fixed cost.

$$Y_m(z) = \max\left[\theta_m K_m(z)^{\alpha_m} H_m(z)^{1-\alpha_m} - F, 0\right]$$

- Firm z sets its price $q_m(z)$ to max profits given all of the other prices.

$$Y_m(z) = \sum_{j=1}^{n} C_m^j(z) + C_m^{rw}(z).$$

$$C_m^j(z) = \frac{\beta_m^{\frac{1}{1-\eta}} (r^j K^j + w^j H^j + q_p \gamma_p N^j + q_s^j \gamma_s N^j)}{q_m(z)^{\frac{1}{1-\rho}} \left[\int_{D^w} q_m(z')^{\frac{-\rho}{1-\rho}} dz' \right]^{\frac{\rho-\eta}{\rho(1-\eta)}} \Delta}$$

$$\Delta = \beta_p^{\frac{1}{1-\eta}} q_p^{-\frac{\eta}{1-\eta}} + \beta_m^{\frac{1}{1-\eta}} \left[\left(\int_{D^w} q_m(z')^{\frac{-\rho}{1-\rho}} dz' \right)^{\frac{-(1-\rho)}{\rho}} \right]^{\frac{-\eta}{1-\eta}} + \beta_s^{\frac{1}{1-\eta}} q_s^{-\frac{\eta}{1-\eta}}$$

- Every firm is uniquely associated with only one variety (symmetry).
- Free entry.
- $D^w = [0, d^w]$ with d^w finite and endogenously determined.

Volume of Trade

Let s^j be the share of country j, $j = 1,\ldots,n$, rw, in the world production of manufactures,

$$s^j = \int_{D^j} Y_m(z)dz \;\; / \int_{D^w} Y_m(z)dz \;\; = Y_m^j / Y_m^w .$$

The imports by country j from the OECD are

$$M_{oe}^j = (1 - s^{rw} - s^j)C_m^j$$
$$M_{oe}^{rw} = (1 - s^{rw})C_m^{rw} .$$

Total imports in the OECD from the other OECD countries are

$$M_{oe}^{oe} = \sum_{j=1}^{n} M_{oe}^j (1 - s^{rw} - \sum_{j=1}^{n} (s^j)^2 / (1 - s^{rw}))C_m^{oe} .$$

OECD in 1990

Country	Share of GDP %	Country	Share of GDP %
Australia	1.79	Japan	18.04
Austria	0.97	Netherlands	1.72
Belgium-Lux	1.26	New Zealand	0.26
Canada	3.45	Norway	0.70
Denmark	0.78	Portugal	0.41
Finland	0.81	Spain	3.00
France	7.26	Sweden	1.40
Germany	9.96	Switzerland	0.17
Greece	0.50	Turkey	0.91
Iceland	0.04	United Kingdom	5.92
Ireland	0.28	United States	33.72
Italy	6.64		

ACCOUNTING FOR THE FACTS

Compare the changes that the model predicts for 1961-1990 with what actually took place.

Focus on key variables:

- OECD-OECD Trade/OECD GDP
- OECD-OECD Trade/OECD-RW Trade
- OECD Manfacturing GDP/OECD GDP

Calibrate to 1990 data.

Backcast to 1961 by imposing changes in parameters:

- relative sizes of countries in the OECD
- populations
- sectoral productivities
- endowments

ACCOUNTING FOR THE FACTS

Benchmark 1990 OECD Data Set
(Billion U.S. dollars)

	Primaries	Manufactures	Services	Total
H_i^{oe}	228	2,884	8,644	11,756
K_i^{oe}	441	775	3,497	4,713
Y_i^{oe}	669	3,659	12,141	16,469
C_i^{oe}	862	3,466	12,141	16,469
$Y_i^{oe} - C_i^{oe}$	-193	193	0	0

ACCOUNTING FOR THE FACTS

Benchmark 1990 Rest of the World Data Set
(Billion U.S. dollars)

	Primaries	**Manufactures**	**Services**	**Total**
Y_i^{rw}	1,223	1,159	3,447	5,829
C_i^{rw}	1,030	1,352	3,447	5,829
$Y_i^{rw} - C_i^{rw}$	193	-193	0	0

ACCOUNTING FOR THE FACTS

- $N^{oe} = 854$, $N^{rw} = 4,428$.
- $\sum_{i=p,m,s} Y_i^{rw} = \sum_{i=p,m,s} C_i^{rw} = 5,829$.
- Set $q_p = q_m(z) = q_s = w = r = 1$ (quantities are 1990 values).
- $\rho = 1/1.2$ (Morrison 1990, Martins, Scarpetta, and Pilat 1996).
- Normalize $d^w = 100$.
- Calibrate H^{rw}, K^{rw} so that benchmark data set is an equilibrium.

- Alternative calibrations of utility parameters γ_p, γ_s, and η.

OECD in 1961

Country	Share of GDP %	Country	Share of GDP %
Austria	0.75	Netherlands	1.37
Belgium-Lux	1.25	Norway	0.60
Canada	4.22	Portugal	0.32
Denmark	0.70	Spain	1.38
France	6.99	Sweden	1.62
Germany	9.71	Switzerland	1.07
Greece	0.50	Turkey	0.83
Iceland	0.03	United Kingdom	8.08
Ireland	0.21	United States	55.74
Italy	4.64		

Numerical Experiments

Calculate equilibrium in 1961:

$$\theta_{p,1961} = \theta_{p,1990}$$

$$\theta_{m,1961} = \theta_{m,1990}/1.014^{29},\ F_{1961} = F_{1990}/1.014^{29}$$

$$\theta_{s,1961} = \theta_{s,1990}/1.005^{29} \text{ (Echevarria 1997)}$$

$$N^{oe} = 536,\ N^{rw} = 2,545$$

Numerical Experiments

Choose H_{1961}^{oe}, K_{1961}^{oe}, H_{1961}^{rw}, K_{1961}^{rw} so that

$$\frac{\sum_{i=p,m,s} Y_{i,1990}^{oe} / N_{1990}^{oe}}{\sum_{i=p,m,s} Y_{i,1961}^{oe} / N_{1961}^{oe}} = 2.400$$

$$\frac{\sum_{i=p,m,s} Y_{i,1990}^{rw} / N_{1990}^{rw}}{\sum_{i=p,m,s} Y_{i,1961}^{rw} / N_{1961}^{rw}} = 2.055$$

$$\frac{K_{1961}^{oe}}{H_{1961}^{oe}} = \frac{K_{1990}^{oe}}{H_{1990}^{oe}}$$

$$\frac{q_{p,1961}(Y_{p,1961}^{rw} - C_{p,1961}^{rw})}{\sum_{i=p,m,s} q_{i,1961} Y_{i,1961}^{rw}} = 0.050$$

How Can the Model Work in Matching the Facts?

- The ratio of trade to product has increased:

  The size distribution of countries has become more equal (Helpman-Krugman).

- Trade has become more concentrated among industrialized countries:

  OECD countries have comparative advantage in manufactures, while the RW has comparative advantage in primaries. Because they are inferior to manufactures, primaries become less important in trade as the world becomes richer (Markusen).

How Can the Model Work in Matching the Facts?

- Trade among industrialized countries is largely intraindustry trade:

  OECD countries export manufactures. Because of taste for variety, every country consumes some manufactures from every other country (Dixit-Stiglitz).

- The different total factor productivity growth rates across sectors imply that the price of manufactures relative to primaries and services has fallen sharply between 1961 and 1990. If price elasticities of demand are not equal to one, a lot can happen.

Experiment 1

$\gamma_p = \gamma_p = \eta = 0$

	1961	1990	Change
Data			
OECD-OECD Trade/OECD GDP	0.053	0.112	111.5%
OECD-OECD Trade/OECD-RW Trade	0.844	1.579	87.1%
OECD Manf GDP/OECD GDP	0.295	0.222	–24.6%
1. $\gamma_p = 0$, $\gamma_s = 0$, $\eta = 0$			
OECD-OECD Trade/OECD GDP	0.108	0.136	25.8%
OECD-OECD Trade/OECD-RW Trade	0.893	1.169	30.9%
OECD Manf GDP/OECD GDP	0.223	0.222	–0.4%

Experiment 2

$\gamma_p = -169.5$, $\gamma_s = 314.7$ to match consumption in RW in 1990, $\eta = 0$

	1961	1990	Change
Data			
OECD-OECD Trade/OECD GDP	0.053	0.112	111.5%
OECD-OECD Trade/OECD-RW Trade	0.844	1.579	87.1%
OECD Manf GDP/OECD GDP	0.295	0.222	–24.6%
2. $\gamma_p = -169.5$, $\gamma_s = 314.7$, $\eta = 0$			
OECD-OECD Trade/OECD GDP	0.103	0.132	28.1%
OECD-OECD Trade/OECD-RW Trade	0.739	1.060	43.6%
OECD Manf GDP/OECD GDP	0.225	0.222	–1.4%

Experiment 3

$\gamma_p = -169.5$, $\gamma_s = 314.7$,
$\eta = 0.559$ to match growth in OECD-OECD Trade/OECD GDP

	1961	1990	Change
Data			
OECD-OECD Trade/OECD GDP	0.053	0.112	111.5%
OECD-OECD Trade/OECD-RW Trade	0.844	1.579	87.1%
OECD Manf GDP/OECD GDP	0.295	0.222	–24.6%
3. $\gamma_p = -169.5$, $\gamma_s = 314.7$, $\eta = 0.559$			
OECD-OECD Trade/OECD GDP	0.063	0.132	111.5%
OECD-OECD Trade/OECD-RW Trade	0.738	1.060	43.7 %
OECD Manf GDP/OECD GDP	0.137	0.222	62.7%

Experiments 4 and 5

$\gamma_p = -169.5$, $\gamma_s = 314.7$, reasonable values of η $(0.5 \geq 1/(1-\eta) \geq 0.1)$

	1961	1990	Change
Data			
OECD-OECD Trade/OECD GDP	0.053	0.112	111.5%
OECD-OECD Trade/OECD-RW Trade	0.844	1.579	87.1%
OECD Manf GDP/OECD GDP	0.295	0.222	–24.6%
4. $\gamma_p = -169.5$, $\gamma_s = 314.7$, $\eta = -1$			
OECD-OECD Trade/OECD GDP	0.118	0.132	11.7%
OECD-OECD Trade/OECD-RW Trade	0.739	1.060	43.5%
OECD Manf GDP/OECD GDP	0.259	0.222	–14.1%
5. $\gamma_p = -169.5$, $\gamma_s = 314.7$, $\eta = -9$			
OECD-OECD Trade/OECD GDP	0.118	0.132	1.6%
OECD-OECD Trade/OECD-RW Trade	0.739	1.060	43.5%
OECD Manf GDP/OECD GDP	0.284	0.222	–21.8%

Sensitivity Analysis:
Alternative Calibration Methodologies

- Alternative specifications of nonhomogeneity
- Gross imports calibration
- Alternative RW endowment calibration
- Alternative RW growth calibration
- Intermediate goods

INTERMEDIATE GOODS?

$$Y_p^j = \min\left[\frac{X_{pp}^j}{a_{pp}}, \frac{\int_{D^w} X_{mp}^j(z)dz}{a_{mp}}, \frac{X_{sp}^j}{a_{sp}}, \theta_p\left(K_p^j\right)^{\alpha_p}\left(H_p^j\right)^{1-\alpha_p}\right]$$

$$Y_m(z) = \min\left[\begin{array}{l}\frac{X_{pm}^j(z)}{a_{pm}}, \frac{\int_{D^w} X_{mm}^j(z,z')dz'}{a_{mm}}, \frac{X_{sm}^j(z)}{a_{sm}}, \\ \theta_m\left(K_m(z)\right)^{\alpha_m}\left(H_m(z)\right)^{1-\alpha_m} - F\end{array}\right]$$

$$Y_s^j = \min\left[\frac{X_{ps}^j}{a_{ps}}, \frac{\int_{D^w} X_{ms}^j(z)dz}{a_{ms}}, \frac{X_{ss}^j}{a_{ss}}, \theta_s\left(K_s^j\right)^{\alpha_s}\left(H_s^j\right)^{1-\alpha_s}\right]$$

Results for Model with Intermediate Goods

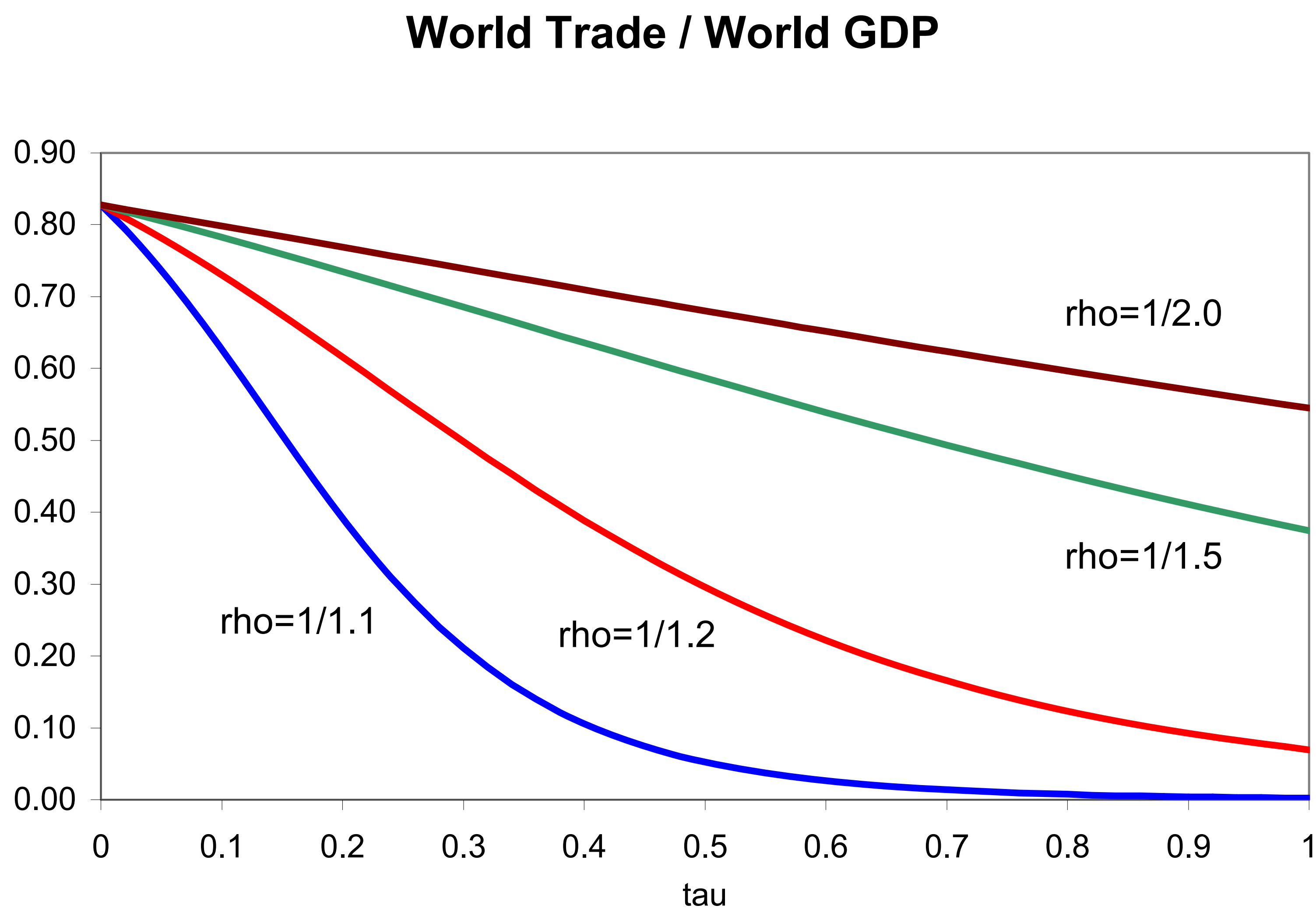
	1961	1990	Change
Data			
OECD-OECD Trade/OECD GDP	0.053	0.112	111.5%
OECD-OECD Trade/OECD-RW Trade	0.844	1.579	87.1%
OECD Manf GDP/OECD GDP	0.295	0.222	–24.6%
4. $\gamma_p = -307.8$, $\gamma_s = 262.2$, $\eta = -1$			
OECD-OECD Trade/OECD GDP	0.323	0.370	14.5%
OECD-OECD Trade/OECD-RW Trade	0.994	1.305	31.3%
OECD Manf GDP/OECD GDP	0.263	0.222	–15.6%
5. $\gamma_p = -307.8$, $\gamma_s = 262.2$, $\eta = -9$			
OECD-OECD Trade/OECD GDP	0.337	0.370	9.7%
OECD-OECD Trade/OECD-RW Trade	0.933	1.305	39.9%
OECD Manf GDP/OECD GDP	0.307	0.222	–27.5%

POLICY?

In a version of our model with n OECD countries, a manufacturing sector, and a uniform ad valorem tariff τ, the ratio of exports to income is given by

$$\frac{M}{Y} = \frac{(n-1)C_f}{Y} = \frac{n-1}{n-1+(1+\tau)^{1/(1-\rho)}}$$

Fixing n to replicate the size distribution of national incomes in the OECD, and setting $\rho = 1/1.2$, a fall in τ from 0.45 to 0.05 produces an increase in the ratio of trade to output as seen in the data.


World Trade / World GDP
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
tau
rho=1/2.0
rho=1/1.5
rho=1/1.2
rho=1/1.1

2. Applied general equilibrium models that put the standard theory to work do not well in predicting the impact of trade liberalization experiences like NAFTA.

Applied general equilibrium models were the only analytical game in town when it came to analyzing the impact of NAFTA in 1992-1993.

Typical sort of model: Static applied general equilibrium model with large number of industries and imperfect competition (Dixit-Stiglitz or Eastman-Stykolt) and finite number of firms in some industries. In some numerical experiments, new capital is placed in Mexico owned by consumers in the rest of North America to account for capital flows.

Examples:
Brown-Deardorff-Stern model of Canada, Mexico, and the United States
Cox-Harris model of Canada
Sobarzo model of Mexico

T. J. Kehoe, "An Evaluation of the Performance of Applied General Equilibrium Models of the Impact of NAFTA," in T. J. Kehoe, T. N. Srinivasan, and J. Whalley, editors, *Frontiers in Applied General Equilibrium Modeling: Essays in Honor of Herbert Scarf*, Cambridge University Press, 2005, 341-77.

Research Agenda:

- Compare results of numerical experiments of models with data.
- Determine what shocks — besides NAFTA policies — were important.
- Construct a simple applied general equilibrium model and perform experiments with alternative specifications to determine what was wrong with the 1992-1993 models.

Applied GE Models Can Do a Good Job!

Spain: Kehoe-Polo-Sancho (1992) evaluation of the performance of the Kehoe-Manresa-Noyola-Polo-Sancho-Serra MEGA model of the Spanish economy: A Shoven-Whalley type model with perfect competition, modified to allow government and trade deficits and unemployment (Kehoe-Serra). Spain's entry into the European Community in 1986 was accompanied by a fiscal reform that introduced a value-added tax (VAT) on consumption to replace a complex range of indirect taxes, including a turnover tax applied at every stage of the production process. What would happen to tax revenues? Trade reform was of secondary importance.

Canada-U.S.: Fox (1999) evaluation of the performance of the Brown-Stern (1989) model of the 1989 Canada-U.S. FTA.

Other changes besides policy changes are important!

Changes in Consumer Prices in the Spanish Model
(Percent)

sector	data 1985-1986	model policy only	model shocks only	model policy&shocks
food and nonalcoholic beverages	1.8	-2.3	4.0	1.7
tobacco and alcoholic beverages	3.9	2.5	3.1	5.8
clothing	2.1	5.6	0.9	6.6
housing	-3.3	-2.2	-2.7	-4.8
household articles	0.1	2.2	0.7	2.9
medical services	-0.7	-4.8	0.6	-4.2
transportation	-4.0	2.6	-8.8	-6.2
recreation	-1.4	-1.3	1.5	0.1
other services	2.9	1.1	1.7	2.8
weighted correlation with data		-0.08	0.87	0.94
variance decomposition of change		0.30	0.77	0.85
regression coefficient *a*		0.00	0.00	0.00
regression coefficient *b*		-0.08	0.54	0.67

Measures of Accuracy of Model Results

1. Weighted correlation coefficient.
2. Variance decomposition of the (weighted) variance of the changes in the data:

$$vardec(y^{data}, y^{model}) = \frac{var(y^{model})}{var(y^{model}) + var(y^{data} - y^{model})}.$$

3, 4. Estimated coefficients a and b from the (weighted) regression

$$x_i^{data} = a + bx_i^{model} + e_i.$$

Changes in Value of Gross Output/GDP in the Spanish Model (Percent)

sector	data 1985-1986	model policy only	model shocks only	model policy&shocks
agriculture	-0.4	-1.1	8.3	6.9
energy	-20.3	-3.5	-29.4	-32.0
basic industry	-9.0	1.6	-1.8	-0.1
machinery	3.7	3.8	1.0	5.0
automobile industry	1.1	3.9	4.7	8.6
food products	-1.8	-2.4	4.7	2.1
other manufacturing	0.5	-1.7	2.3	0.5
construction	5.7	8.5	1.4	10.3
commerce	6.6	-3.6	4.4	0.4
transportation	-18.4	-1.5	1.0	-0.7
services	8.7	-1.1	5.8	4.5
government services	7.6	3.4	0.9	4.3
weighted correlation with data		0.16	0.80	0.77
variance decomposition of change		0.11	0.73	0.71
regression coefficient *a*		-0.52	-0.52	-0.52
regression coefficient *b*		0.44	0.75	0.67

Changes in Trade/GDP in the Spanish Model (Percent)

direction of exports	data 1985-1986	model policy only	model shocks only	model policy&shocks
Spain to rest of E.C.	-6.7	-3.2	-4.9	-7.8
Spain to rest of world	-33.2	-3.6	-6.1	-9.3
rest of E.C. to Spain	14.7	4.4	-3.9	0.6
rest of world to Spain	-34.1	-1.8	-16.8	-17.7
weighted correlation with data		0.69	0.77	0.90
variance decomposition of change		0.02	0.17	0.24
regression coefficient *a*		-12.46	2.06	5.68
regression coefficient *b*		5.33	2.21	2.37

Changes in Composition of GDP in the Spanish Model (Percent of GDP)

variable	data 1985-1986	model policy only	model shocks only	model policy&shocks
wages and salaries	-0.53	-0.87	-0.02	-0.91
business income	-1.27	-1.63	0.45	-1.24
net indirect taxes and tariffs	1.80	2.50	-0.42	2.15
correlation with data		0.998	-0.94	0.99
variance decomposition of change		0.93	0.04	0.96
regression coefficient *a*		0.00	0.00	0.00
regression coefficient *b*		0.73	-3.45	0.85
private consumption	-0.81	-1.23	-0.51	-1.78
private investment	1.09	1.81	-0.58	1.32
government consumption	-0.02	-0.06	-0.38	-0.44
government investment	-0.06	-0.06	-0.07	-0.13
exports	-3.40	-0.42	-0.69	-1.07
-imports	3.20	-0.03	2.23	2.10
correlation with data		0.40	0.77	0.83
variance decomposition of change		0.20	0.35	0.58
regression coefficient *a*		0.00	0.00	0.00
regression coefficient *b*		0.87	1.49	1.24

Public Finances in the Spanish Model
(Percent of GDP)

variable	data 1985-1986	model policy only	model shocks only	model policy&shocks
indirect taxes and subsidies	2.38	3.32	-0.38	2.98
tariffs	-0.58	-0.82	-0.04	-0.83
social security payments	0.04	-0.19	-0.03	-0.22
direct taxes and transfers	-0.84	-0.66	0.93	0.26
government capital income	-0.13	-0.06	0.02	-0.04
correlation with data		0.99	-0.70	0.92
variance decomposition of change		0.93	0.08	0.86
regression coefficient *a*		-0.06	0.35	-0.17
regression coefficient *b*		0.74	-1.82	0.80

Models of NAFTA Did Not Do a Good Job!

Ex-post evaluations of the performance of applied GE models are essential if policy makers are to have confidence in the results produced by this sort of model.

Just as importantly, they help make applied GE analysis a scientific discipline in which there are well-defined puzzles and clear successes and failures for alternative hypotheses.

Changes in Trade/GDP
in Brown-Deardorff-Stern Model (Percent)

variable	data 1988-1999	model
Canadian exports	52.9	4.3
Canadian imports	57.7	4.2
Mexican exports	240.6	50.8
Mexican imports	50.5	34.0
U.S. exports	19.1	2.9
U.S. imports	29.9	2.3
weighted correlation with data		0.64
variance decomposition of change		0.08
regression coefficient *a*		23.20
regression coefficient *b*		2.43

Changes in Canadian Trade/GDP in Cox-Harris Model (Percent)

variable	data 1988-2000	model
total trade	57.2	10.0
trade with Mexico	280.0	52.2
trade with United States	76.2	20.0
weighted correlation with data		0.99
variance decomposition of change		0.52
regression coefficient *a*		38.40
regression coefficient *b*		1.93

Changes in Canadian Exports/GDP in the Brown-Deardorff-Stern Model (Percent)

	exports to Mexico		exports to United States	
sector	1988–1999	model	1988–1999	model
agriculture	122.6	3.1	78.8	3.4
mining and quarrying	-34.0	-0.3	77.4	0.4
food	257.1	2.2	121.1	8.9
textiles	2066.0	-0.9	277.5	15.3
clothing	3956.0	1.3	234.3	45.3
leather products	3171.2	1.4	76.9	11.3
footwear	427.0	3.7	102.6	28.3
wood products	9248.7	4.7	140.2	0.1
furniture and fixtures	10385.3	2.7	150.3	12.5
paper products	158.1	-4.3	8.2	-1.8
printing and publishing	1100.6	-2.0	105.4	-1.6
chemicals	534.6	-7.8	104.0	-3.1
petroleum and products	86.3	-8.5	26.7	0.5
rubber products	4710.3	-1.0	162.6	9.5
nonmetal mineral products	3016.7	-1.8	113.1	1.2
glass products	1518.3	-2.2	104.9	30.4
iron and steel	176.1	-15.0	36.9	12.9
nonferrous metals	34.7	-64.7	8.0	18.5
metal products	1380.0	-10.0	127.0	15.2
nonelectrical machinery	1297.1	-8.9	85.4	3.3
electrical machinery	2919.2	-26.2	246.4	14.5
transportation equipment	4906.7	-4.4	85.9	10.7
miscellaneous manufactures	898.7	-12.1	195.9	-2.1
weighted correlation with data		-0.24		0.25
variance decomposition of change		0.0005		0.02
regression coefficient *a*		452.48		76.55
regression coefficient *b*		-11.35		1.64

Changes in Mexican Exports/GDP in the Brown-Deardorff-Stern Model (Percent)

sector	exports to Canada 1988–1999	exports to Canada model	exports to United States 1988–1999	exports to United States model
agriculture	-21.8	-4.1	-17.2	2.5
mining and quarrying	-35.5	27.3	-20.7	26.9
food	-11.7	10.8	-10.0	7.5
textiles	77.2	21.6	521.3	11.8
clothing	689.3	19.2	320.3	18.6
leather products	160.7	36.2	22.7	11.7
footwear	196.2	38.6	-13.0	4.6
wood products	59.6	15.0	-17.8	-2.7
furniture and fixtures	1772.9	36.2	111.8	7.6
paper products	63.5	32.9	-62.0	13.9
printing and publishing	2918.1	15.0	297.3	3.9
chemicals	126.4	36.0	5.5	17.0
petroleum and products	273.5	32.9	-61.5	34.1
rubber products	1172.1	-6.7	107.6	-5.3
nonmetal mineral products	108.1	5.7	1.9	3.7
glass products	74.9	13.3	39.2	32.3
iron and steel	41.7	19.4	59.8	30.8
nonferrous metals	-33.6	138.1	-53.4	156.5
metal products	316.2	41.9	162.4	26.8
nonelectrical machinery	128.9	17.3	194.6	18.5
electrical machinery	252.3	137.3	75.1	178.0
transportation equipment	94.8	3.3	155.1	6.2
miscellaneous manufactures	622.2	61.1	202.2	43.2
weighted correlation with data		0.82		-0.03
variance decomposition of change		0.56		0.40
regression coefficient *a*		80.14		75.18
regression coefficient *b*		1.23		-0.02

Changes in U.S. Exports/GDP in the Brown-Deardorff-Stern Model (Percent)

	exports to Canada		exports to Mexico	
sector	1988–1999	model	1988–1999	model
agriculture	-24.8	5.1	5.9	7.9
mining and quarrying	-22.9	1.0	-19.7	0.5
food	40.8	12.7	67.4	13.0
textiles	45.3	44.0	1326.3	18.6
clothing	147.6	56.7	1322.2	50.3
leather products	-37.1	7.9	998.9	15.5
footwear	-2.5	45.7	222.9	35.4
wood products	0.2	6.7	275.7	7.0
furniture and fixtures	181.0	35.6	330.2	18.6
paper products	56.9	18.9	160.6	-3.9
printing and publishing	0.7	3.9	239.8	-1.1
chemicals	53.8	21.8	160.7	-8.4
petroleum and products	-57.8	0.8	154.6	-7.4
rubber products	57.4	19.1	659.6	12.8
nonmetal mineral products	-11.5	11.9	393.1	0.8
glass products	28.1	4.4	771.7	42.3
iron and steel	41.1	11.6	115.6	-2.8
nonferrous metals	-1.1	-6.7	223.1	-55.1
metal products	48.5	18.2	783.0	5.4
nonelectrical machinery	-5.3	9.9	242.0	-2.9
electrical machinery	38.5	14.9	1192.6	-10.9
transportation equipment	-4.0	-4.6	586.9	9.9
miscellaneous manufactures	46.9	11.5	330.6	-9.4
weighted correlation with data		0.82		-0.20
variance decomposition of change		0.40		0.0007
regression coefficient *a*		2.47		346.92
regression coefficient *b*		1.55		-7.25

Changes in Canadian Trade/GDP in the Cox-Harris Model (Percent)

sector	total exports 1988-2000	total exports model	total imports 1988-2000	total imports model
agriculture	-13.7	-4.1	4.6	7.2
forestry	215.5	-11.5	-21.5	7.1
fishing	81.5	-5.4	107.3	9.5
mining	21.7	-7.0	32.1	4.0
food, beverages, and tobacco	50.9	18.6	60.0	3.8
rubber and plastics	194.4	24.5	87.7	13.8
textiles and leather	201.1	108.8	24.6	18.2
wood and paper	31.9	7.3	97.3	7.2
steel and metal products	30.2	19.5	52.2	10.0
transportation equipment	66.3	3.5	29.7	3.0
machinery and appliances	112.9	57.1	65.0	13.3
nonmetallic minerals	102.7	31.8	3.6	7.3
refineries	20.3	-2.7	5.1	1.5
chemicals and misc. manufactures	53.3	28.1	92.5	10.4
weighted correlation with data		0.49		0.85
variance decomposition of change		0.32		0.08
regression coefficient *a*		41.85		22.00
regression coefficient *b*		0.81		3.55

Changes in Mexican Trade/GDP in the Sobarzo Model (Percent)

sector	exports to North America 1988–2000	exports to North America model	imports from North America 1988–2000	imports from North America model
agriculture	-15.3	-11.1	-28.2	3.4
mining	-23.2	-17.0	-50.7	13.2
petroleum	-37.6	-19.5	65.9	-6.8
food	5.2	-6.9	11.8	-5.0
beverages	42.0	5.2	216.0	-1.8
tobacco	-42.3	2.8	3957.1	-11.6
textiles	534.1	1.9	833.2	-1.2
wearing apparel	2097.3	30.0	832.9	4.5
leather	264.3	12.4	621.0	-0.4
wood	415.1	-8.5	168.9	11.7
paper	12.8	-7.9	68.1	-4.7
chemicals	41.9	-4.4	71.8	-2.7
rubber	479.0	12.8	792.0	-0.1
nonmetallic mineral products	37.5	-6.2	226.5	10.9
iron and steel	35.9	-4.9	40.3	17.7
nonferrous metals	-40.3	-9.8	101.2	9.8
metal products	469.5	-4.4	478.7	9.5
nonelectrical machinery	521.7	-7.4	129.0	20.7
electrical machinery	3189.1	1.0	749.1	9.6
transportation equipment	224.5	-5.0	368.0	11.2
other manufactures	975.1	-4.5	183.6	4.2
weighted correlation with data		0.61		0.23
variance decomposition of change		0.0004		0.002
regression coefficient *a*		495.08		174.52
regression coefficient *b*		30.77		5.35

What Do We Learn from these Evaluations?

The Spanish model seems to have been far more successful in predicting the consequences of policy changes than the three models of NAFTA, but

- Kehoe, Polo, and Sancho (KPS) knew the structure of their model well enough to precisely identify the relationships between the variables in their model with those in the data;

- KPS were able to use the model to carry out numerical exercises to incorporate the impact of exogenous shocks.

KPS had an incentive to show their model in the best possible light.

3. Much of the growth of trade after a trade liberalization experience is growth on the extensive margin. Models need to allow for corner solutions or fixed costs.

T. J. Kehoe and K. J. Ruhl, “How Important is the New Goods Margin in International Trade?” Federal Reserve Bank of Minneapolis, 2002.

What happens to the **least-traded** goods:

Over the business cycle?
During trade liberalization?

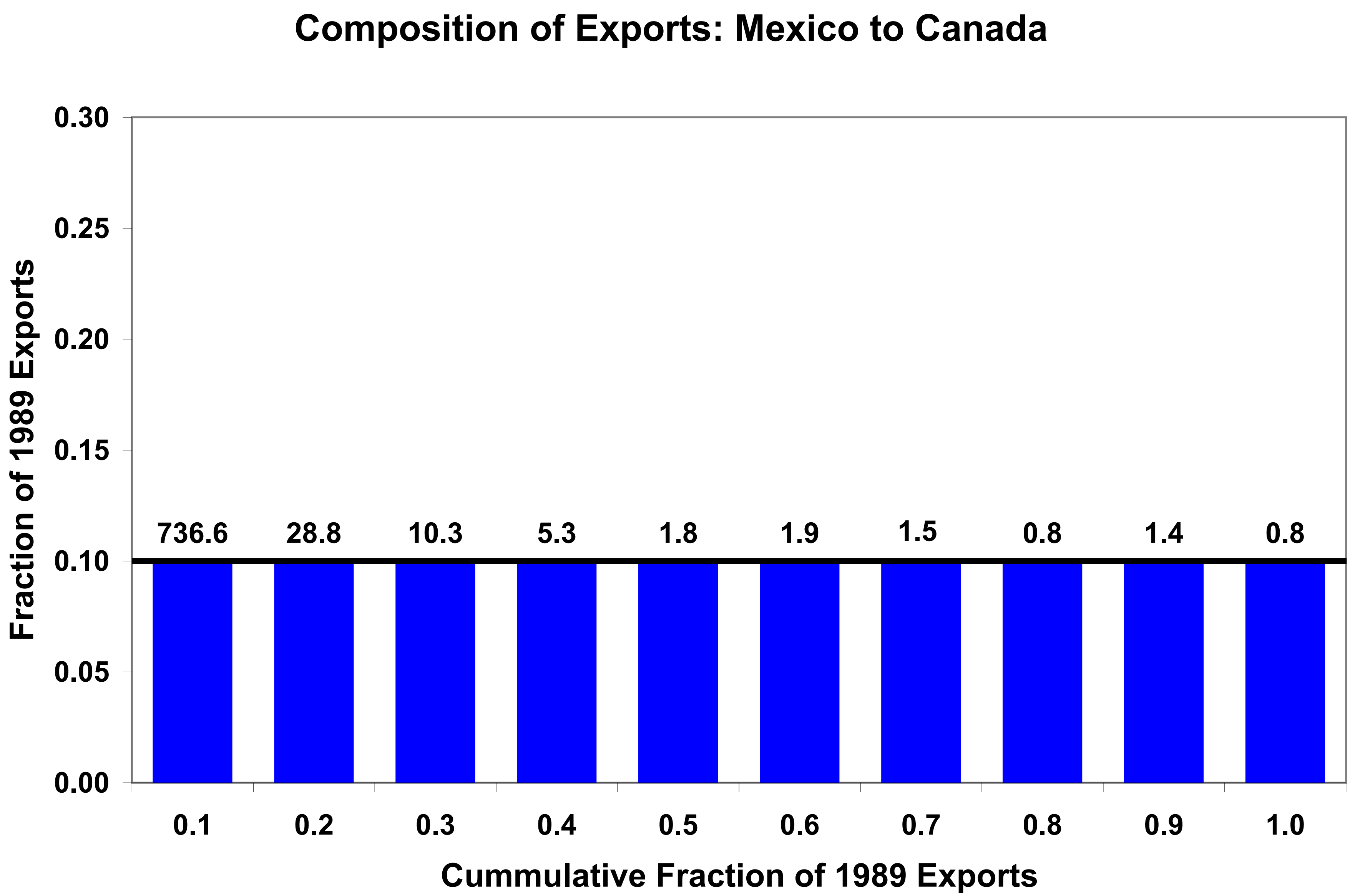
Indirect evidence on the extensive margin

Evidence on the Extensive Margin

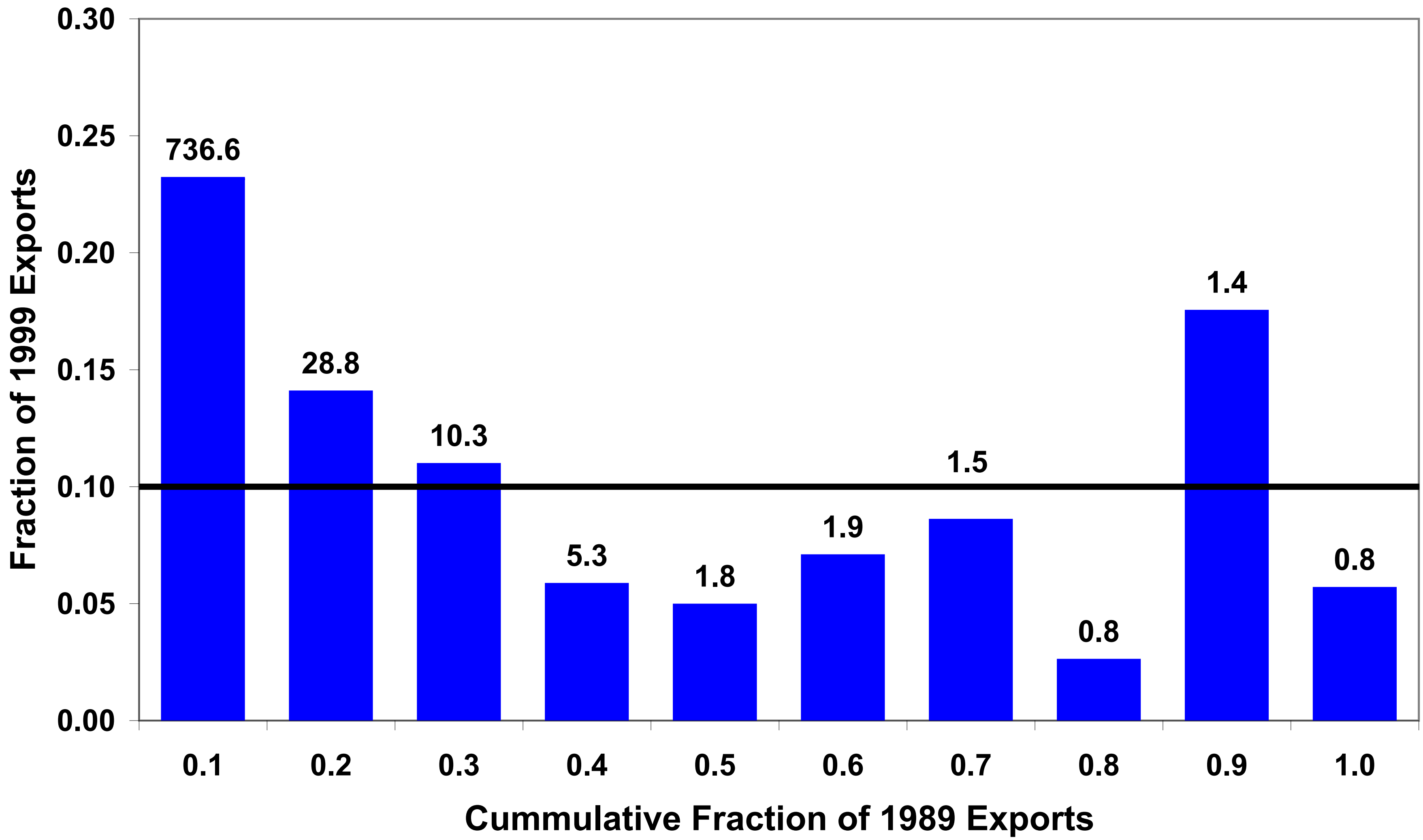
- Data
  - 4 digit SITC bilateral trade data (OECD)
  - 789 codes in revision 2

- Least Traded Goods
  - Look 5 years before trade agreement
  - Rank codes from lowest value of exports to highest based on average of first 3 years in sample
  - Lowest decile of codes = least-traded goods

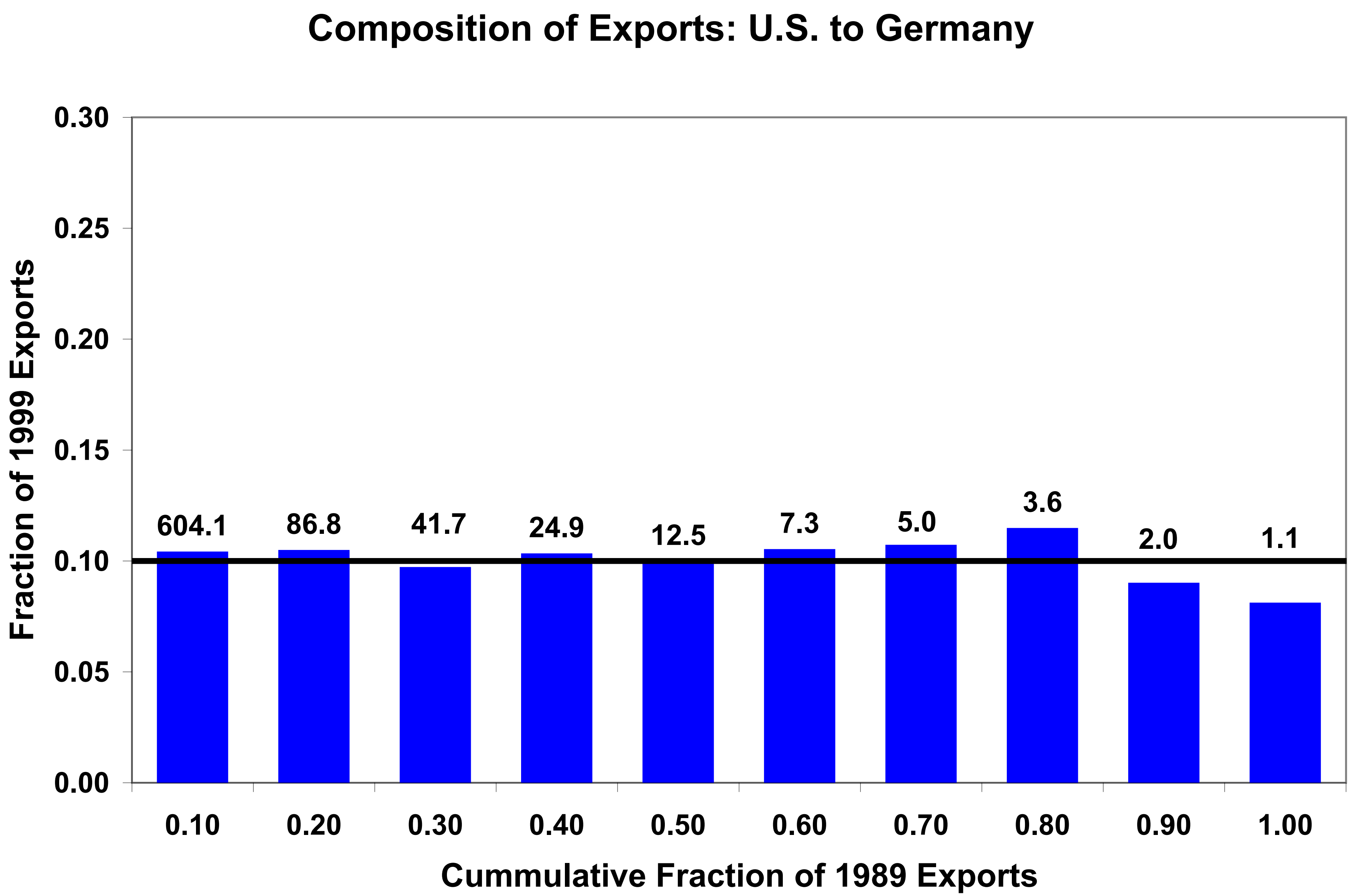
- Two Episodes
  - Canada-Mexico during NAFTA
  - United States-Germany in 1990s


Composition of Exports: Mexico to Canada
Fraction of 1989 Exports
0.30
0.25
0.20
0.15
0.10
0.05
0.00
736.6
28.8
10.3
5.3
1.8
1.9
1.5
0.8
1.4
0.8
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Cummulative Fraction of 1989 Exports

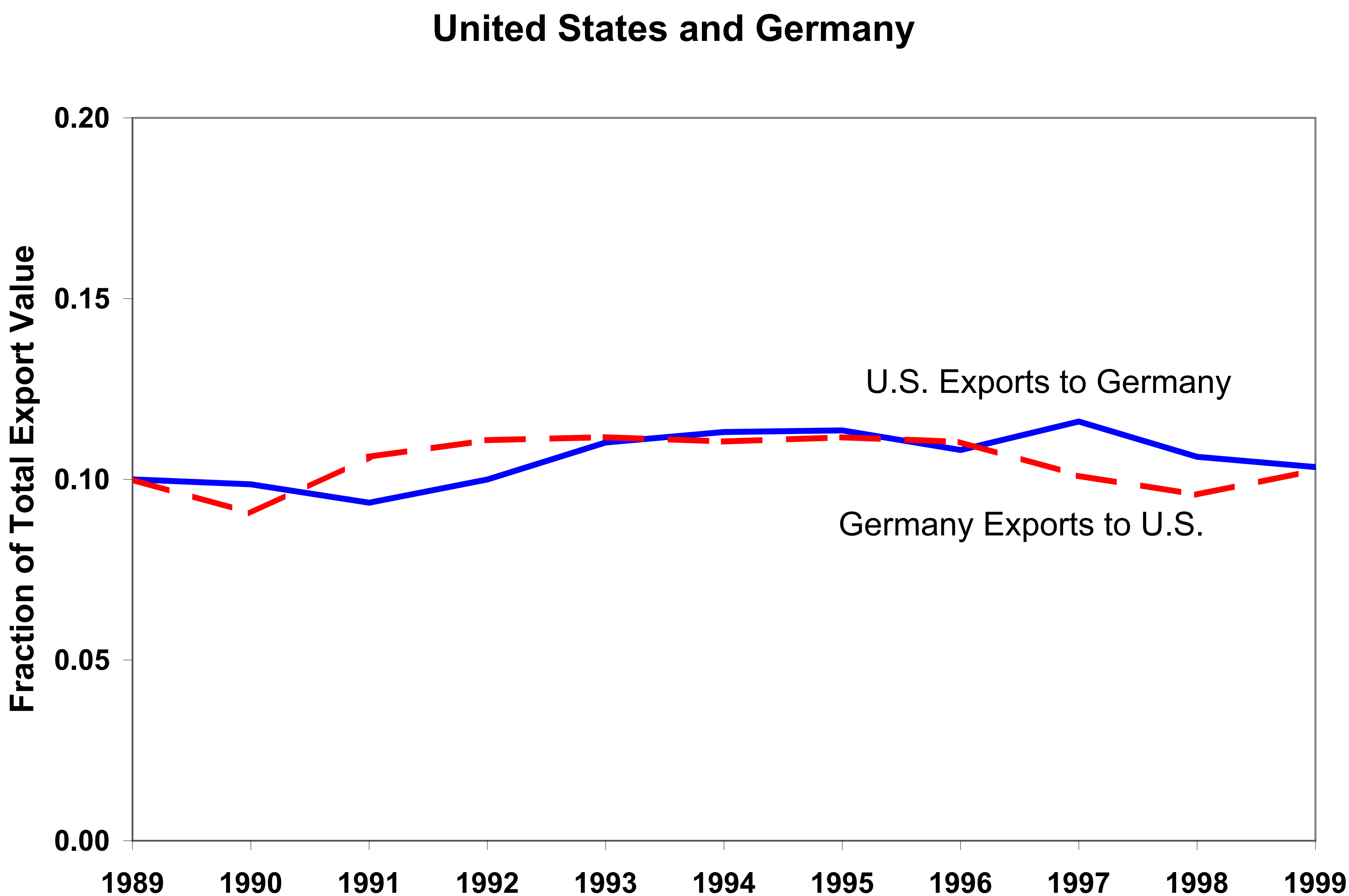
Composition of Exports: Mexico to Canada



Exports: Mexico to the Canada
Fraction of Total Export Value
0.30
0.20
0.10
0.00
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999



Composition of Exports: U.S. to Germany
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Fraction of 1999 Exports
604.1
86.8
41.7
24.9
12.5
7.3
5.0
3.6
2.0
1.1
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Cummulative Fraction of 1989 Exports


United States and Germany
Fraction of Total Export Value
0.20
0.15
0.10
0.05
0.00
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
U.S. Exports to Germany
Germany Exports to U.S.

Armington aggregator

$$x_i^{mex} = \theta_i \left(\alpha_{i,can}^{mex} x_{i,can}^{mex\ \rho} + \alpha_{i,mex}^{mex} x_{i,mex}^{mex\ \rho} + \alpha_{i,us}^{mex} x_{i,us}^{mex\ \rho} + \alpha_{i,rw}^{mex} x_{i,rw}^{mex\ \rho} \right)^{1/\rho}$$

Dixit-Stiglitz/Ethier aggregator

$$x_i^{mex} = \theta_i \left(\sum_{j=1}^{n_i} x_{i,j}^{mex\ \rho} \right)^{1/\rho}$$

modified to allow for home country bias

$$x_i^{mex} = \theta_i \left(\alpha_{i,can}^{mex} \sum_{j=1}^{n_{i,can}} x_{i,j,can}^{mex\ \rho} + \alpha_{i,mex}^{mex} \sum_{j=1}^{n_{i,mex}} x_{i,j,mex}^{mex\ \rho} \right.$$
$$\left. + \alpha_{i,us}^{mex} \sum_{j=1}^{n_{i,us}} x_{i,j,us}^{mex\ \rho} + \alpha_{i,rw}^{mex} \sum_{j=1}^{n_{i,rw}} x_{i,j,rw}^{mex\ \rho} \right)^{1/\rho}$$

Ricardian model with a continuum of goods $x \in [0,1]$

production technologies $y(x) = \ell(x)/a(x),\ y^*(x) = \ell^*(x)/a^*(x)$

ad valorem tariffs $\tau,\ \tau^*$

$$(1+\tau^*)wa(x) < w^* a^*(x) \Leftrightarrow \frac{a(x)}{a^*(x)} < \frac{w^*}{(1+\tau^*)w}$$

$\Rightarrow$home country produces good and exports it to the foreign country.

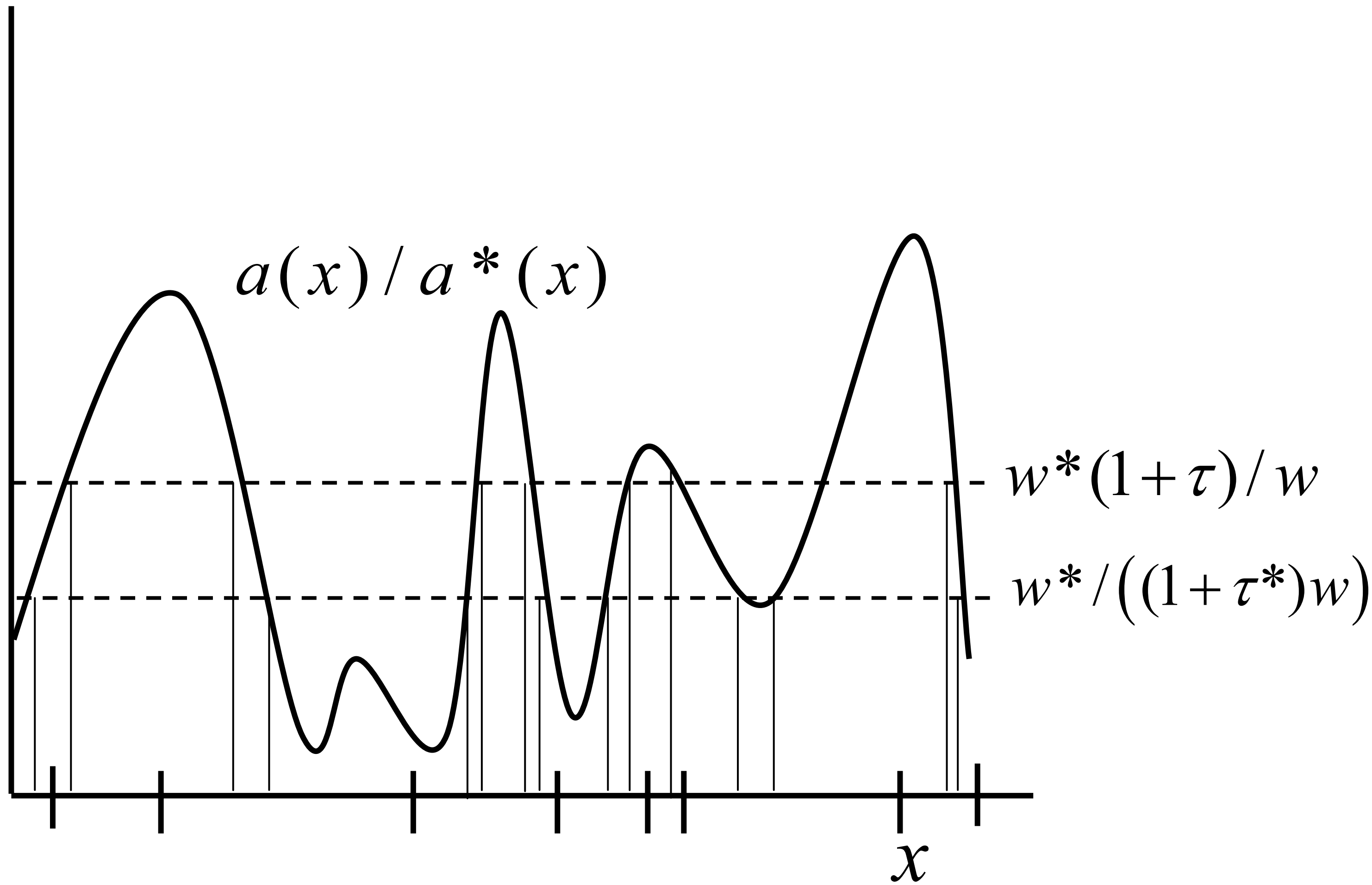
$$\frac{a(x)}{a^*(x)} > \frac{(1+\tau)w^*}{w}$$

$\Rightarrow$foreign country produces good and exports it to the home country.

$$\frac{(1+\tau)w^*}{w} > \frac{a(x)}{a^*(x)} > \frac{w^*}{(1+\tau^*)w}$$

$\Rightarrow$ good is not traded.

Lowering tariffs generates trade in previously nontraded goods.



4. Fixed costs seem better than Ricardian corner solutions for reconciling time series data on real exchange rate fluctuations with data on trade growth after liberalization experiences.

K. J. Ruhl, “Solving the Elasticity Puzzle in International Economics,” University of Texas at Austin, 2005.

The "Armington" Elasticity

- Elasticity of substitution between domestic and foreign goods
- Crucial elasticity in international economic models
- International Real Business Cycle (IRBC) models:
    - Terms of trade volatility
    - Net exports and terms of trade co-movements
- Applied General Equilibrium (AGE) Trade models:
    - Trade response to tariff changes

The Elasticity Puzzle

- Time series (Business Cycles):
  - Estimates are low
  - Relative prices volatile
  - Quantities less volatile

- Panel studies (Trade agreement):
  - Estimates are high
  - Small change in tariffs (prices)
  - Large change in quantities

Time Series Estimates: Low Elasticity (1.5)

Study	Range
Reinert and Roland Holst (1992)	$[0.1, 3.5]$
Reinert and Shiells (1993)	$[0.1, 1.5]$
Gallaway et al. (2003)	$[0.2, 4.9]$

Trade Liberalization Estimates: High Elasticity (9.0)

Study	Range
Clausing (2001)	$[8.9, 11.0]$
Head and Reis (2001)	$[7.9, 11.4]$
Romalis (2002)	$[4.0, 13.0]$

Why do the Estimates Differ?

- Time series – no liberalization:
  - Change in trade volume from goods already traded
  - Change mostly on the *intensive margin*

- Trade liberalization:
  - Change in intensive margin *plus*
  - New types of goods being traded
  - Change on the *extensive margin*

Modeling the Extensive Margin

- Model: extensive margin from export entry costs
- Empirical evidence of entry costs
  - Roberts and Tybout (1997)
  - Bernard and Wagner (2001)
  - Bernard and Jensen (2003)
  - Bernard, Jensen and Schott (2003)

The Effects of Entry Costs

- Business cycle shocks:
  - Small extensive margin effect

- Trade liberalization:
  - Big extensive margin effect

- Asymmetry creates different empirical elasticities

Model Overview

- Two countries: $\{h, f\}$, with labor L
- Infinitely lived consumers
- No international borrowing/lending
- Continuum of traded goods plants in each country
    - Differentiated goods
    - Monopolistic competitors
    - Heterogeneous productivity
- Export entry costs
    - Differs across plants: second source of heterogeneity
- Non-traded good, competitive market: A
- Tariff on traded goods (iceberg): τ

Uncertainty

- At date t, H possible events, $\eta_t = 1,\ldots,\text{H}$
- Each event is associated with a vector of productivity shocks:

$$z_t = \left[z_h\left(\eta_t\right), z_f\left(\eta_t\right) \right]$$

- First-order Markov process with transition matrix Λ

$$\lambda_{\eta\eta'} = \text{pr}\left(\eta_{t+1} = \eta' \middle| \eta_t = \eta\right)$$

Traded Good Plants

- Traded good technology:

$$y(\phi,\kappa) = z\phi\, l$$

- Plant heterogeneity (ϕ,κ)
    - constant, idiosyncratic productivity: ϕ
    - export entry cost: κ
    - plant of type (ϕ,κ)

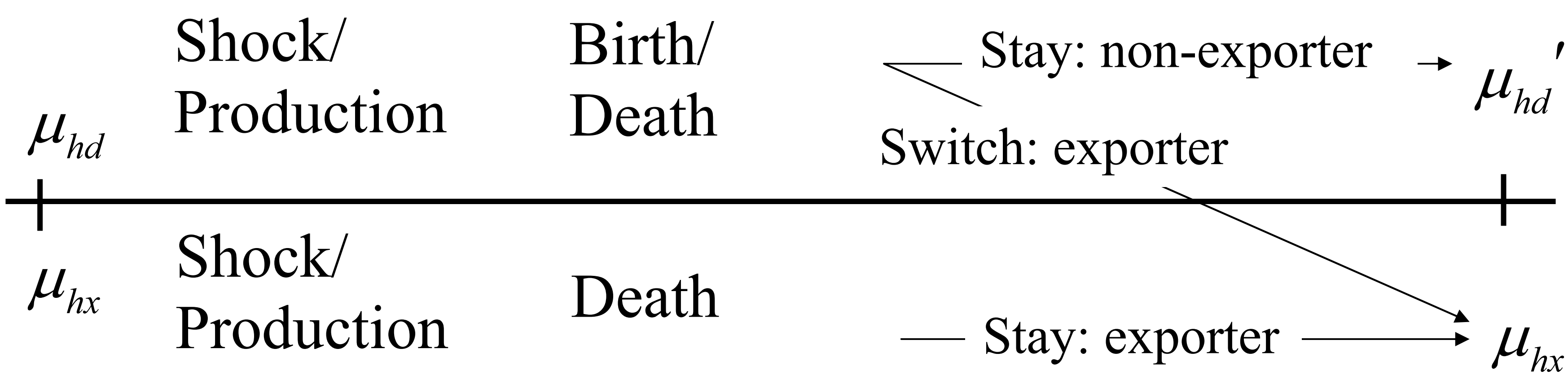
- ν plants born each period with distribution $F(\phi,\kappa)$
- Fraction δ of plants exogenously die each period

Timing

$\mu_{hx}(\phi,\kappa)$: plants of type (ϕ,κ) who paid entry cost

$\mu_{hd}(\phi,\kappa)$: plants of type (ϕ,κ) who have not paid entry cost

$\mu = (\mu_{hd}, \mu_{hx}, \mu_{fd}, \mu_{fx})$



Consumers

$$\max_{q,c_h^h(\iota),c_f^h(\iota)} \gamma \log\left(C\right) + \left(1-\gamma\right)\log\left(A\right)$$

s.t.

$$C = \left[\int_{\iota \in \mathrm{I}_h^h(\mu)} c_h^h\left(\iota\right)^{\rho} d\iota + \int_{\iota \in \mathrm{I}_f^h(\mu)} c_f^h\left(\iota\right)^{\rho} d\iota \right]^{\frac{1}{\rho}}$$

$$\int_{\iota \in \mathrm{I}_h^h(\mu)} p_h^h\left(\iota\right) c_h^h\left(\iota\right) d\iota + \int_{\iota \in \mathrm{I}_f^h(\mu)} \left(1+\tau\right) p_f^h\left(\iota\right) c_f^h\left(\iota\right) d\iota + p_{hA} A = L + \Pi_h$$

Non-traded Good

$$\max \; p_{hA}(\eta,\mu)A - l$$
$$\text{s.t. } \; A = z_h(\eta)l$$

Normalize $w_h = 1$, implying $p_{hA}(\eta,\mu) = z_h(\eta)$

Traded Goods: Static Profit Maximization

$$\pi_d\left(p_h^h, l; \phi, \kappa, \eta, \mu\right) = \max_{p_h^h,\, l}\; p_h^h z(\eta)\phi l - l$$

$$\text{s.t.} \qquad z(\eta)\phi l = \tilde{c}_h^h\left(p_h^h; \eta, \mu\right)$$

$$\pi_x\left(p_h^f, l; \phi, \kappa, \eta, \mu\right) = \max_{p_h^f,\, l}\; p_h^f z(\eta)\phi l - l$$

$$\text{s.t.} \qquad z(\eta)\phi l = \tilde{c}_h^f\left(p_h^f; \eta, \mu\right)$$

Pricing rules:

$$p_h^h(\phi, \kappa, \eta, \mu) = p_h^f(\phi, \kappa, \eta, \mu) = \frac{1}{\rho\phi z(\eta)}$$

Dynamic Choice: Export or Sell Domestically

- Exporter's Value Function:

$$V_x(\phi,\kappa,\eta,\mu) = d(\eta,\mu)\big(\pi_d(\phi,\kappa,\eta,\mu) + \pi_x(\phi,\kappa,\eta,\mu)\big)$$
$$+(1-\delta)\beta\sum_{\eta'} V_x(\phi,\kappa,\eta',\mu')\lambda_{\eta\eta'}$$

s.t. $\mu' = \mathrm{M}(\eta,\mu)$

- $d(\eta,\mu)$ = multiplier on budget constraint

• Non-exporter's Value Function:

$$V_d\left(\phi,\kappa,\eta,\mu\right)=$$

$$\max\left\{\pi_d\left(\phi,\kappa,\eta,\mu\right)d\left(\eta,\mu\right)+\beta\left(1-\delta\right)\sum_{\eta'}V_d\left(\phi,\kappa,\eta',\mu'\right)\lambda_{\eta\eta'},\right.$$

$$\left.\left[\pi_d\left(\phi,\kappa,\eta,\mu\right)-\kappa\right]d\left(\eta,\mu\right)+\beta\left(1-\delta\right)\sum_{\eta'}V_x\left(\phi,\kappa,\eta',\mu'\right)\lambda_{\eta\eta'}\right\}$$

s.t. $\mu'=\mathrm{M}\left(\eta,\mu\right)$

Equilibrium

- Cutoff level of productivity for each value of the entry cost
- For a plant of type (ϕ, κ)

  If $\phi \geq \hat{\phi}_{\kappa}(\eta, \mu)$ export and sell domestically

  If $\phi < \hat{\phi}_{\kappa}(\eta, \mu)$ only sell domestically

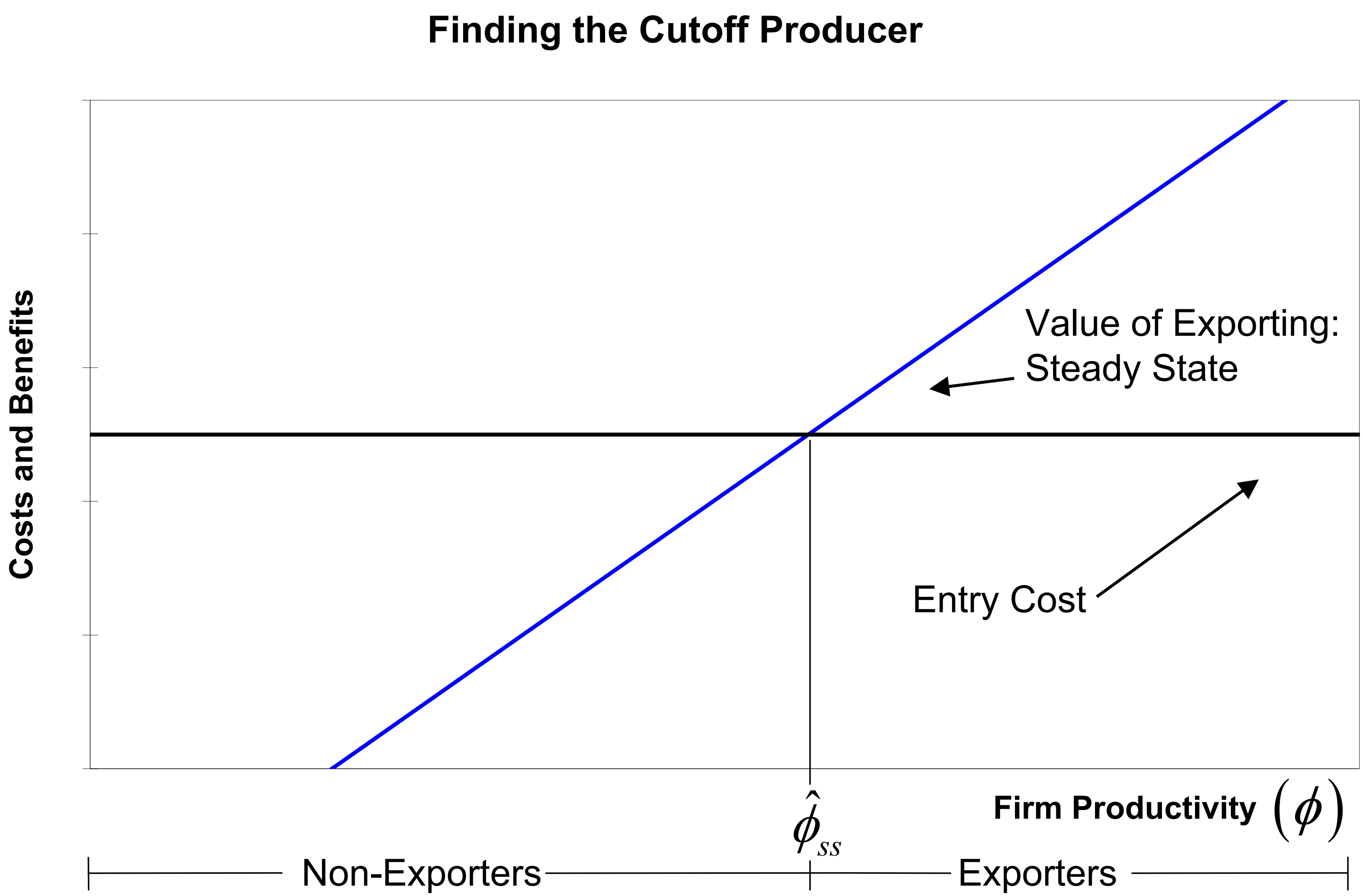
- In Equilibrium
  - "Low" productivity/"high" entry cost plants sell domestic
  - "High" productivity/"low" entry cost plants also export
  - Similar to Melitz (2003)

Determining Cutoffs

- For the cutoff plant:
  - entry cost = discounted, expected value of exporting

- $\hat{\phi}_{\kappa}(\eta,\mu)$ is the level of productivity, ϕ, that solves:

$$\underbrace{d\ (\eta,\mu)\kappa}_{\text{entry cost}} = \underbrace{(1-\delta)\beta\left[\sum_{\eta'} V_x(\phi,\kappa,\eta',\mu')\lambda_{\eta\eta'} - \sum_{\eta'} V_d(\phi,\kappa,\eta',\mu')\lambda_{\eta\eta'}\right]}_{\text{expected value of exporting}}$$


Finding the Cutoff Producer
Costs and Benefits
Value of Exporting:
Steady State
Entry Cost
Firm Productivity (ϕ)
$\hat{\phi}_{ss}$
Non-Exporters
Exporters

Choosing Parameters

- Set $\sigma = \frac{1}{1-\rho} = 2$ and $\tau = 0.15$

- Calibrate to the United States (1987) and a symmetric partner.

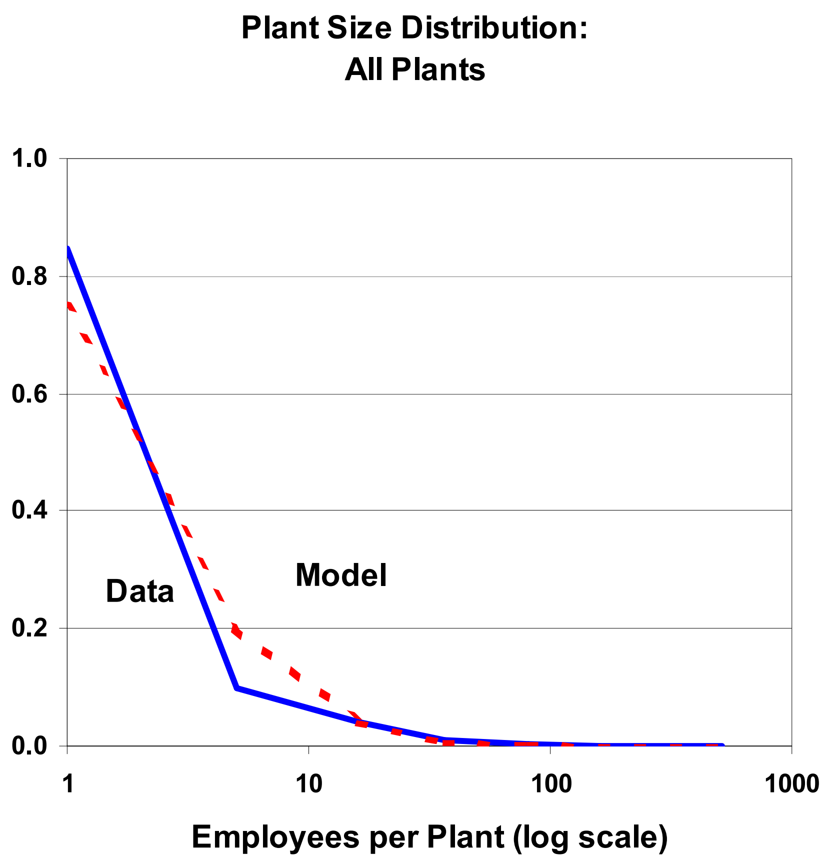
Parameters	
β	Annual real interest rate (4%)
γ	Share of manufactures in GDP (18%)
δ	Annual loss of jobs from plant deaths as percentage of employment (Davis et. al., 1996) (6%)

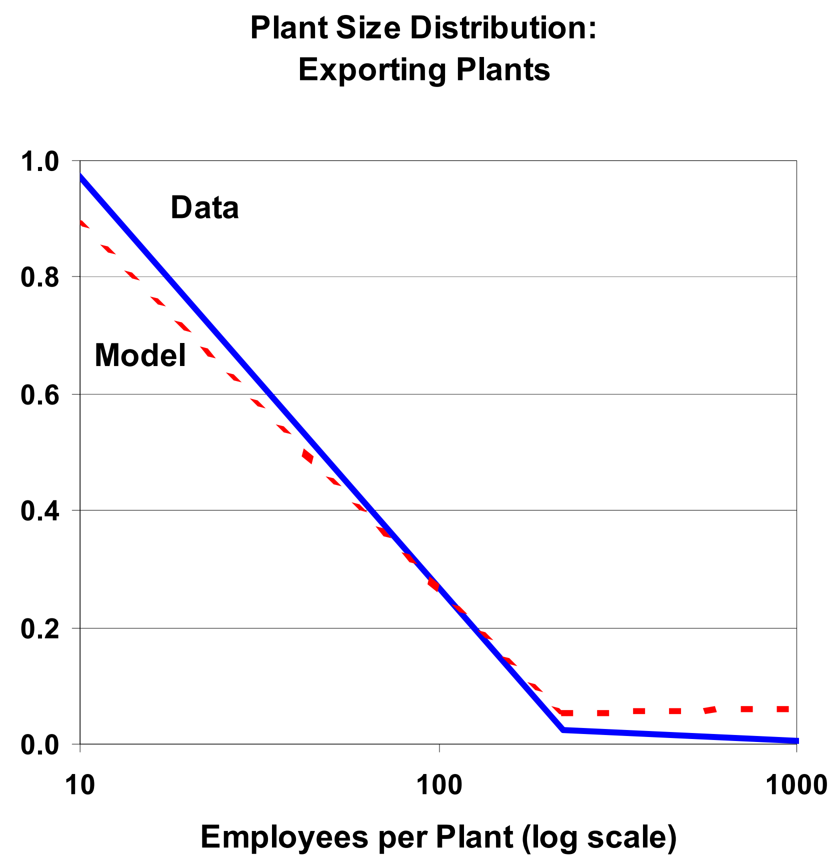
Other Parameters

- Distribution over new plants:

$$F_{\kappa}(\phi) = \frac{1}{\phi^{\theta_{\phi}}} \qquad\qquad F_{\phi}(\kappa) = \frac{1}{(\bar{\kappa} - \kappa)^{\theta_{\kappa}}}$$

- $\bar{\kappa}$, $\bar{\phi}$, ν, $\theta_{\phi}, \theta_{\kappa}$ jointly determine:
  - Average plant size (12 employees)
  - Standard deviation of plant sizes (892)
  - Average exporting plant size (15 employees)
  - Standard deviation of exporting plant sizes (912)
  - Fraction of production that is exported (9%)


Plant Size Distribution:
All Plants
1.0
0.8
0.6
0.4
0.2
0.0
1
10
100
1000
Data
Model
Employees per Plant (log scale)


Plant Size Distribution:
Exporting Plants
1.0
0.8
0.6
0.4
0.2
0.0
10
100
1000
Data
Model
Employees per Plant (log scale)

Productivity Process

- Two shocks, low and high:

$$z_i = 1 - \varepsilon$$
$$z_i = 1 + \varepsilon$$

- Countries have symmetric processes with Markov Matrix

$$\Lambda_i = \begin{bmatrix} \bar{\lambda} & 1-\bar{\lambda} \\ 1-\bar{\lambda} & \bar{\lambda} \end{bmatrix}$$

- ε: standard deviation of the U.S. Solow Residuals (1.0%)
- $\bar{\lambda}$: autocorrelation of the U.S. Solow Residuals (0.90)

How does Trade Liberalization Differ from Business Cycles?

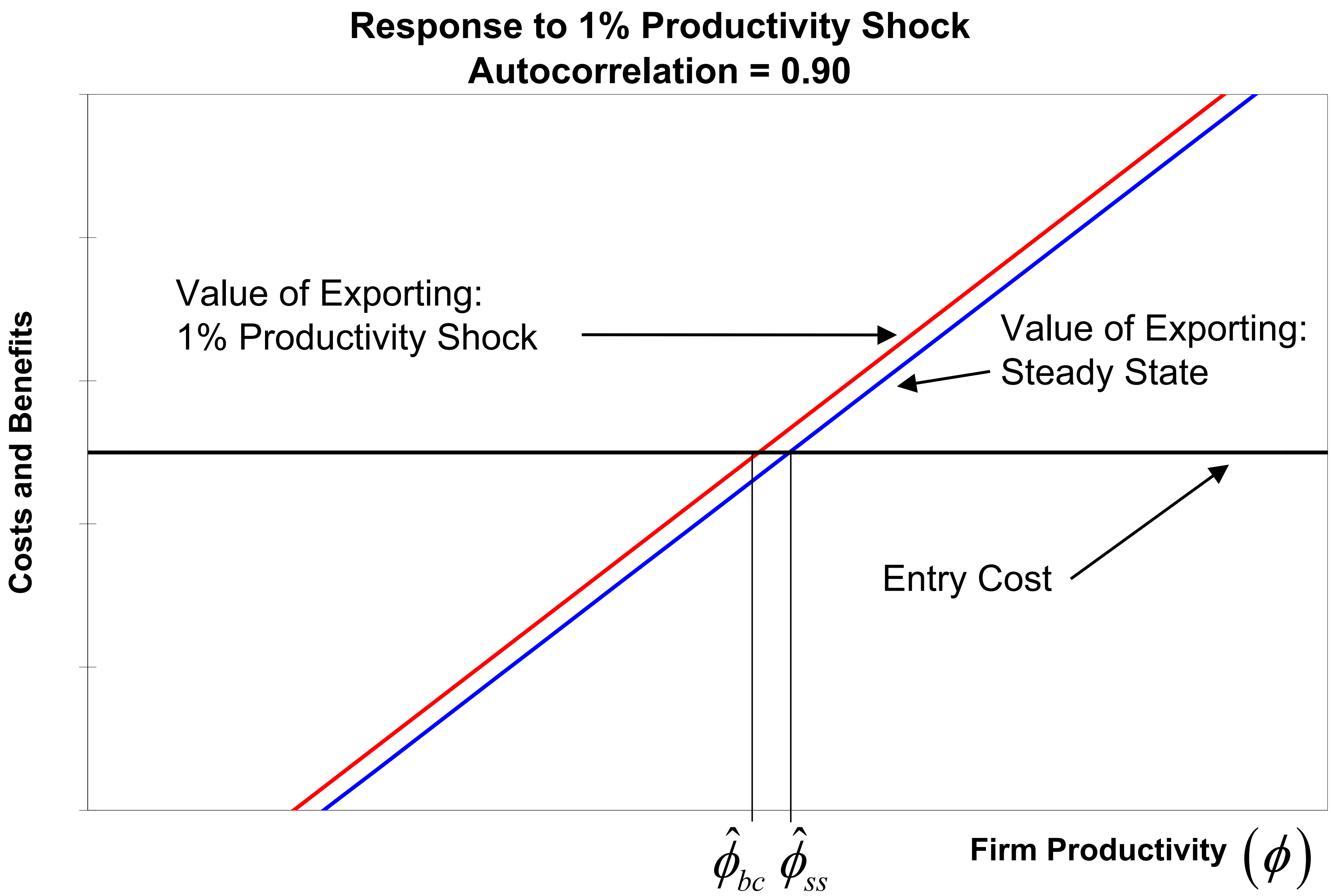
- Trade liberalization
  - Permanent changes
  - Large magnitudes

- Business cycles
  - Persistent, but not permanent changes
  - Small magnitudes

Developing Intuition: Persistent vs. Permanent Shocks

- 1% positive productivity shock in foreign country
  - Shock is persistent – autocorrelation of 0.90

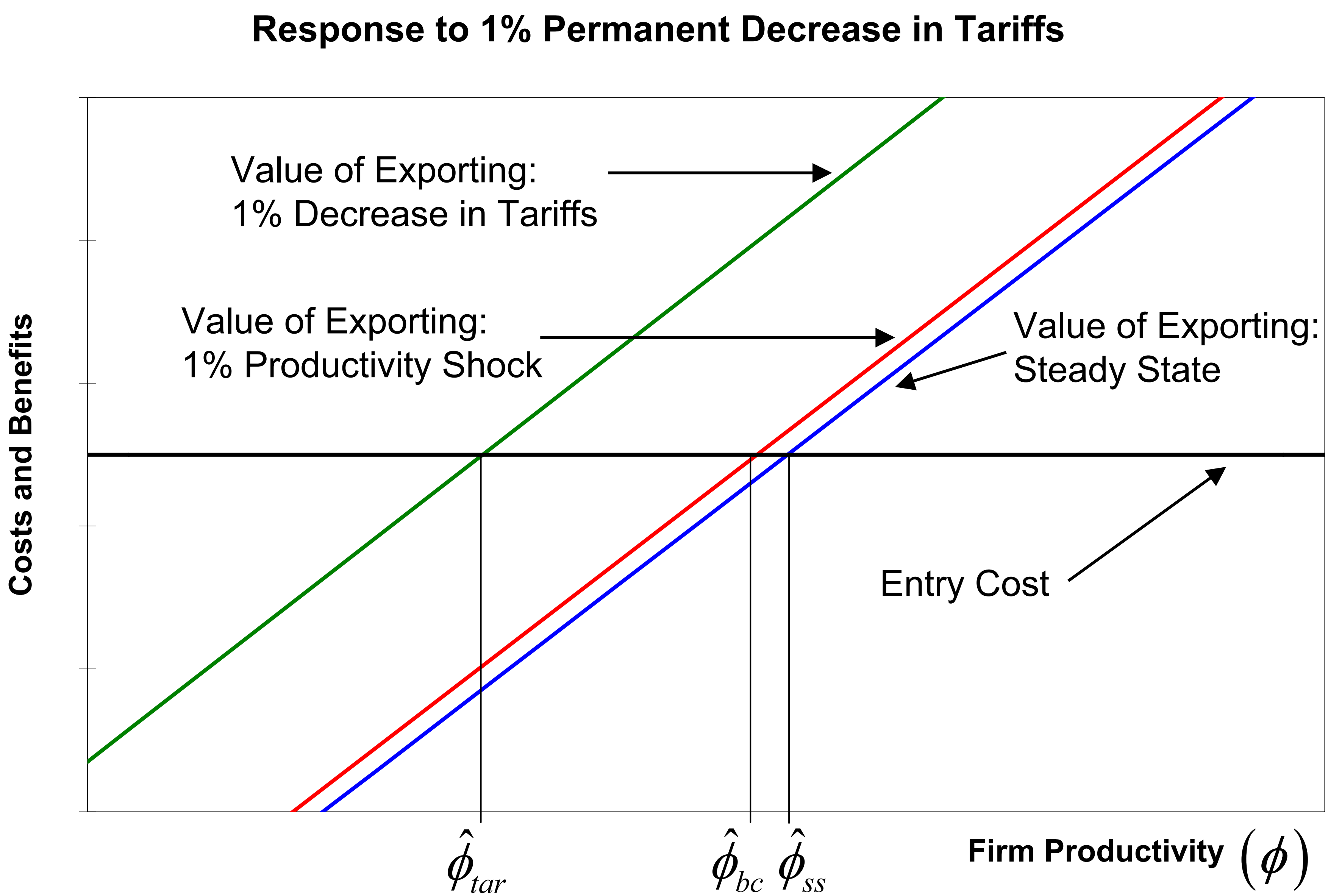
- 1% decrease in tariffs
  - Change in tariffs is permanent


Response to 1% Productivity Shock
Autocorrelation = 0.90
Costs and Benefits
Value of Exporting:
1% Productivity Shock
Value of Exporting:
Steady State
Entry Cost
$\hat{\phi}_{bc}$ $\hat{\phi}_{ss}$
Firm Productivity (ϕ)

Response to a 1% Foreign Productivity Shock

Increase in imports on intensive margin	=	1.89%
Increase in imports on extensive margin	=	0.16%
Total increase in imports	=	2.05%
Change in consumption of home goods	=	-0.10%

$$\frac{\text{\% Change Imports/Dom. Cons.}}{\text{\% Change Price}} = \frac{2.17}{0.99} = 2.19$$


Response to 1% Permanent Decrease in Tariffs
Value of Exporting:
1% Decrease in Tariffs
Value of Exporting:
1% Productivity Shock
Value of Exporting:
Steady State
Entry Cost
Costs and Benefits
$\hat{\phi}_{tar}$
$\hat{\phi}_{bc}$
$\hat{\phi}_{ss}$
Firm Productivity (ϕ)

Response to a 1% Tariff Reduction

Increase in imports on intensive margin	=	1.42%
Increase in imports on extensive margin	=	3.04%
Total increase in imports	=	4.46%
Change in consumption of home goods	=	-0.33%

$$\frac{\text{\% Change Imports/Dom. Cons.}}{\text{\% Change Tariff}} = \frac{4.81}{1.00} = 4.81$$

Quantitative Results

- Two experiments

- Trade liberalization
  - Eliminate 15% tariff
  - Compute elasticity across tariff regimes

- Time series regressions
  - Use model to generate simulated data
  - Estimate elasticity as in the literature

Trade Liberalization Elasticity

Variable	Entry Costs (% change)	No Entry Costs (% change)
Exports	87.1	30.5
Imports/Dom. Cons.	93.0	32.2
Exporting Plants	37.7	0.0
Implied Elasticity	6.2	2.1

Elasticity in the Time Series

- Simulate: produce price/quantity time series
- Regress:

$$\log\left(C_{f,t} / C_{h,t}\right) = \alpha + \sigma \log\left(p_{h,t} / p_{f,t}\right) + \varepsilon_t$$

Parameter	Estimate
α (standard error)	-0.015 (6.36e-04)
σ (standard error)	1.39 (0.06)
R- squared	0.30

Conclusion

- Gap between dynamic macro models and trade models
  - Partially closes the gap
  - Modeling firm behavior as motivated by the data
  - Step towards better modeling of trade policy

- Single model can account for the elasticity puzzle
  - Time series elasticity of 1.4
  - Trade liberalization elasticity of 6.2

5. Growth theory needs to be reconsidered in the light of trade theory. In particular, a growth model that includes trade can have the opposite convergence properties from a model of closed economies.

C. Bajona and T. J. Kehoe, "On Dynamic Heckscher-Ohlin Models II: Infinitely-Lived Consumers," Federal Reserve Bank of Minneapolis, 2004.

Trade and Growth

In 2004 Mexico has income per capita of 6500 U.S. dollars. In 1935 the United Stated had income per capita of about 6600 U.S. dollars (real 2004 U.S. dollars).

To study what will happened in Mexico over the next 70 years, should we study what happened to the United States since 1935?

…or should we take into account that the United States was the country with the highest income in the world in 1935, while Mexico has a very large trade relation with the United States — a country with a level of income per capita approximately 6 times larger in 2004?

We study this question using the Heckscher-Ohlin model of international trade: Countries differ in their initial endowments of capital per worker.

The General Dynamic Heckscher-Ohlin Model

n countries

countries differ in initial capital-labor ratios $\bar{k}_0^i$

and in size of population L^i.

two traded goods — a capital intensive good and a labor intensive good

$$y_j = \phi_j(k_j, \ell_j)$$

$$\frac{\phi_{1L}(k/\ell,1)}{\phi_{1K}(k/\ell,1)} < \frac{\phi_{2L}(k/\ell,1)}{\phi_{2K}(k/\ell,1)}$$

nontraded investment good

$$x = f(x_1, x_2)$$

Feasibility:

$$\sum_{i=1}^{n} L^i (c^i_{jt} + x^i_{jt}) = \sum_{i=1}^{n} L^i y^i_{jt} = \sum_{i=1}^{n} L^i \phi_j (k^i_{jt}, \ell^i_{jt}).$$

$$k^i_{1t} + k^i_{2t} = k^i_t$$

$$\ell^i_{1t} + \ell^i_{2t} = 1$$

$$k^i_{t+1} - (1-\delta) k^i_t = x^i_t = f(x^i_{1t}, x^i_{2t})$$

Infinitely-Lived Consumers

consumer in country i, $i = 1,...,n$:

$$\max \sum_{t=0}^{\infty} \beta^t u(c^i_{1t}, c^i_{2t})$$

$$\text{s.t. } p_{1t}c^i_{1t} + p_{2t}c^t_{2t} + q^i_t x^i_t + b^i_{t+1} = w^i_t + (1 + r^{bi}_t)b^i_t + r^i_t k^i_t$$

$$k^i_{t+1} - (1-\delta)k^i_t = x^i_t$$

$$c^i_{jt} \geq 0,\ x^i_t \geq 0,\ b^i_t \geq -B$$

$$k^i_0 = \overline{k}^i_0,\ b^i_0 = 0.$$

Notice that since p_{1t} and p_{2t} are equalized across countries by trade, we can set

$$q^i_t = q_t = 1.$$

The factor prices w^i_t and r^i_t are potentially different across countries. International borrowing and lending:

$$\sum_{i=1}^{n} L^i b_t^i = 0,$$

No international borrowing and lending:

$$b_t^i = 0.$$

International borrowing and lending implies that $r_t^{bi} = r_t^{b}$, $t = 1, 2, \ldots.$ No arbitrage implies that $r_t^i = r_t = r_t^b + \delta$.

Integrated Equilibrium Approach

Characterization and computation of equilibrium is relatively easy when we can solve for equilibrium of an artificial world economy in which we ignore restrictions on factor mobility and then disaggregate the consumption, production, and investment decisions.

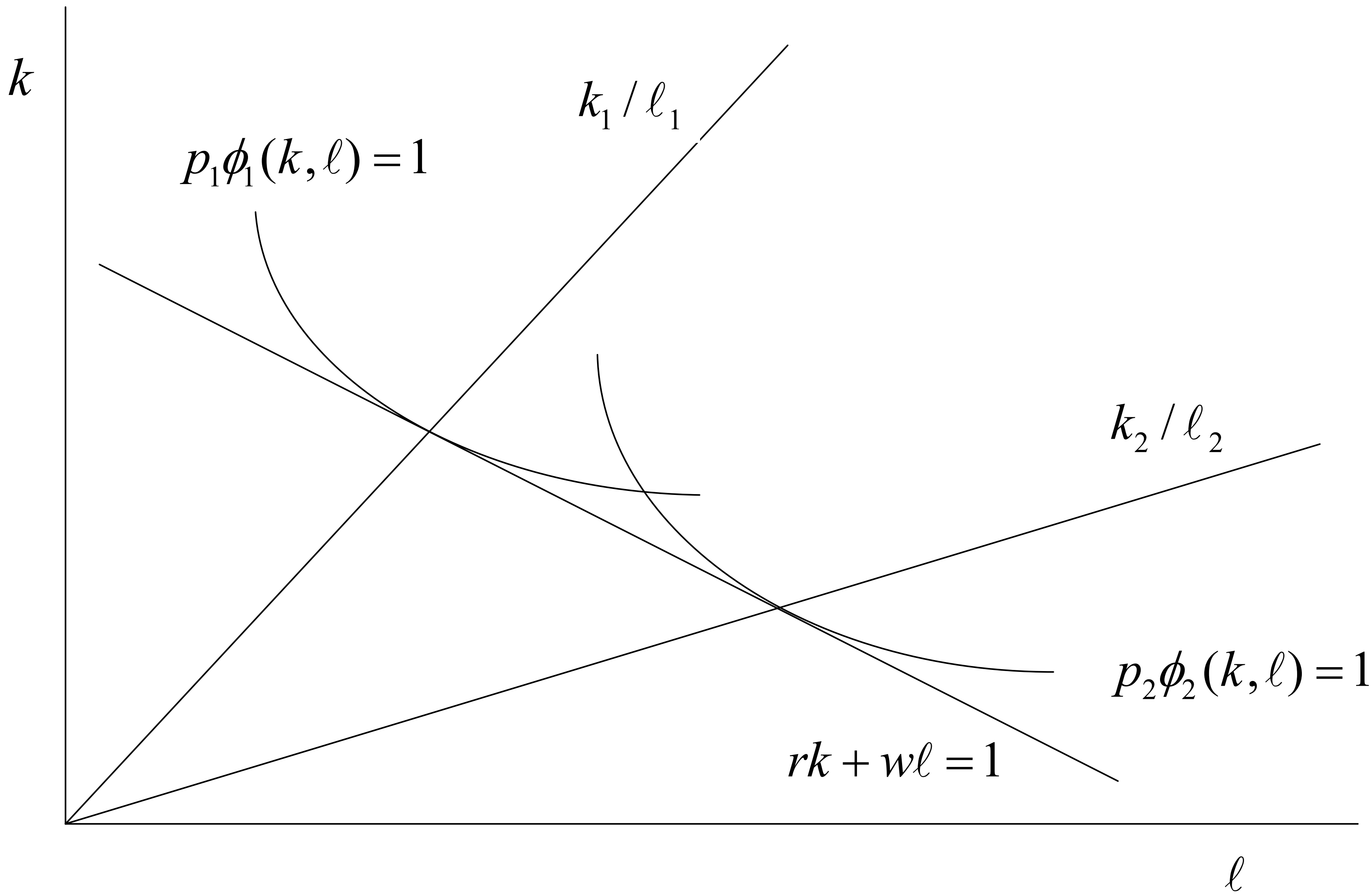
This is a guess-and-verify approach: We first solve for the integrated equilibrium of the world economy and then we see if we can disaggregate the consumption, production, and investment decisions.

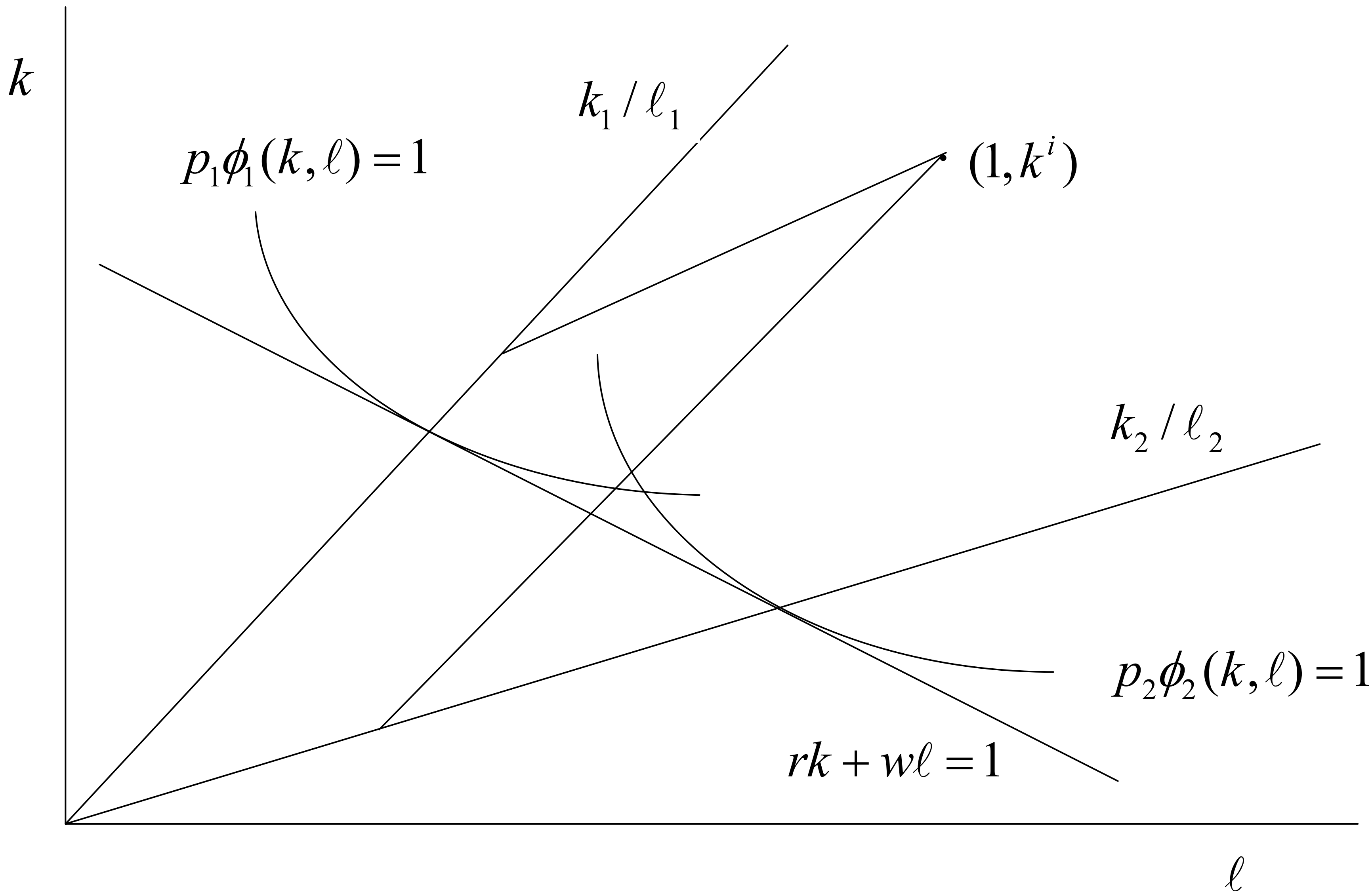
Potential problem: We cannot assign each country nonnegative production plans for each of the two goods while maintaining factor prices equal to those in the world equilibrium.

Another potential problem: We cannot assign each country nonnegative investment.

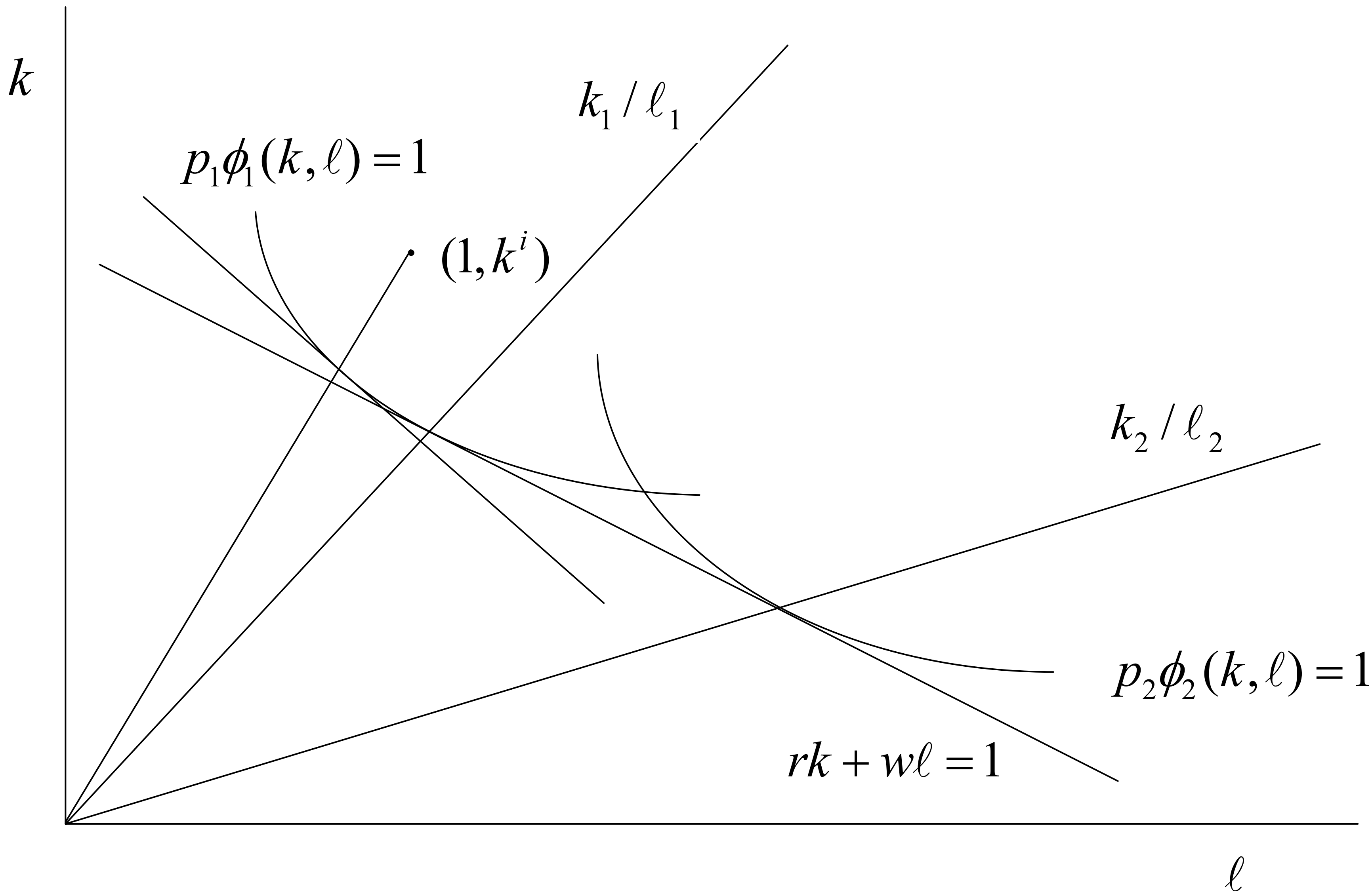
If the integrated equilibrium approach does not work, it could be very difficult to calculate an equilibrium.

We would have to determine the pattern of specialization over an infinite time horizon.


k
k_1 / ℓ_1
$p_1\phi_1(k,\ell) = 1$
k_2 / ℓ_2
$p_2\phi_2(k,\ell) = 1$
$rk + w\ell = 1$
ℓ



k
k_1 / ℓ_1
$p_1\phi_1(k,\ell) = 1$
$(1, k^i)$
k_2 / ℓ_2
$p_2\phi_2(k,\ell) = 1$
$rk + w\ell = 1$
ℓ



k
k_1 / ℓ_1
$p_1\phi_1(k,\ell)=1$
$(1,k^i)$
k_2 / ℓ_2
$p_2\phi_2(k,\ell)=1$
$rk+w\ell=1$
ℓ

Results for General Model

International borrowing and lending implies factor price equalization in period $t = 1, 2, \ldots$ Production plans and international trade patterns are indeterminate.

Any steady state or sustained growth path has factor price equalization.

If there exists a steady state in which the total capital stock is positive or a sustained growth path, then there exists a continuum of such steady states or sustained growth paths, indexed by the distribution of world capital $\hat{k}^1 / \hat{k}, \ldots, \hat{k}^n / \hat{k}$.

International trade occurs in every steady state or sustained growth path of the model in which $\hat{k}^i / \hat{k} \neq 1$ for some i.

We focus on models with no international borrowing and lending.

For analysis of general model with infinitely lived consumers and comparison with model with overlapping generations, see

C. Bajona and T. J. Kehoe (2006), "Demographics in Dynamic Heckscher-Ohlin Models: Overlapping Generations versus Infinitely Lived Consumers."

Ventura Model

$$u(c_1,c_2) = v\big(f(c_1,c_2)\big) = \log\big(f(c_1,c_2)\big)$$

$$\phi_1(k_1,\ell_1) = k_1$$

$$\phi_2(k_2,\ell_2) = \ell_2$$

$$f(x_1,x_2) = \begin{cases} d\left(a_1 x_1^b + a_2 x_2^b\right)^{1/b} & \text{if } b \neq 0 \\ d x_1^{a_1} x_2^{a_2} & \text{if } b = 0 \end{cases}.$$

Ventura (1997) examines the continuous-time version of this model.

In the Ventura model, we can solve for the equilibrium of the world economy by solving a one-sector growth model in which $c_t = f(c_{1t}, c_{2t})$:

$$\begin{gathered}\max \sum_{t=0}^{\infty} \beta^t \log c_t \\ \text{s.t. } c_t + x_t = f(k_t, 1) \\ k_{t+1} - (1-\delta)k_t = x_t \\ c_t \geq 0,\ k_t \geq 0 \\ k_0 = \bar{k}_0.\end{gathered}$$

If $b < 0$ and $1/\beta - 1 + \delta > da_1^{1/b}$, the equilibrium converges to $\hat{k} = 0$.

If $b > 0$ and $1/\beta - 1 + \delta < da_1^{1/b}$, the economy grows without bound, and the equilibrium converges to a sustained growth path.

In every other case, the equilibrium converges to a steady state in which $f_K(\hat{k}, 1) = 1/\beta - 1 + \delta$.

The 2 sectors matter a lot for disaggregating the integrated equilibrium!

In particular, we cannot solve for the equilibrium values of the variables for one of the countries by solving an optimal growth problem for that country in isolation.

Instead, the equilibrium path for k_t^i and the steady state value of $\hat{k}^i$ depends on $\overline{k}_0^i$ as well as on the path for k_t and the steady state value of $\hat{k}$.

Proposition: Let $y_t^i = p_{1t} y_{1t}^i + p_{2t} y_{2t}^i = r_t k_t^i + w_t$. Suppose that $x_t^i > 0$ for all i and all t. Then

$$\frac{y_{t+1}^i - y_{t+1}}{y_{t+1}} = \frac{r_{t+1} c_t / y_{t+1}}{r_t c_{t-1} / y_t} \left(\frac{y_t^i - y_t}{y_t} \right)$$

If $\delta = 1$,

$$\frac{y_{t+1}^i - y_{t+1}}{y_{t+1}} = \frac{s_{t+1}}{s_t} \left(\frac{y_t^i - y_t}{y_t} \right)$$

where $s_t = c_t / y_t$.

Proof: The first-order conditions from the consumers' problems are

$$\frac{c_t^i}{c_{t-1}^i} = \frac{c_t}{c_{t-1}} = \beta(1+r_t-\delta).$$

The demand functions are

$$c_t^i = (1-\beta)\left[\sum_{s=t}^{\infty}\left(\prod_{\tau=t+1}^{s}\frac{1}{1+r_\tau-\delta}\right)w_s + (1+r_t-\delta)k_t^i\right]$$

$$c_t^i - c_t = (1-\beta)(1+r_t-\delta)(k_t^i - k_t).$$

The budget constraint implies that

$$c_t^i - c_t + k_{t+1}^i - k_{t+1} = (1+r_t-\delta)(k_t^i - k_t).$$

Combining these conditions, we obtain

$$k_{t+1}^i - k_{t+1} = \frac{c_t}{c_{t-1}}(k_t^i - k_t).$$

The difference between a country's income per worker and the world's income per worker can be written as

$$y_{t+1}^{i} - y_{t+1} = r_{t+1}(k_{t+1}^{i} - k_{t+1}).$$

Using the expression for $k_{t+1}^{i} - k_{t+1}$ found above and operating, we obtain:

$$\frac{y_{t+1}^{i} - y_{t+1}}{y_{t+1}} = \frac{r_{t+1}c_t / y_{t+1}}{r_t c_{t-1} / y_t}\left(\frac{y_t^{i} - y_t}{y_t}\right).$$

In the case $\delta = 1$ this becomes (using $c_{t+1} / c_t = \beta r_{t+1}$),

$$\frac{y_{t+1}^{i} - y_{t+1}}{y_{t+1}} = \frac{s_{t+1}}{s_t}\left(\frac{y_t^{i} - y_t}{y_t}\right),$$

where $s_t = c_t / y_t$. ■

$$\frac{y_t^i - y_t}{y_t} = \frac{s_t}{s_0}\left(\frac{y_0^i - y_0}{y_0}\right)$$

Proposition. Suppose that $\delta = 1$, that $0 < k_0 < \hat{k}$, and that $x_t^i > 0$ for all i and all t. Then

if $b > 0$, differences in relative income levels decrease over time;

if $b = 0$, differences in relative income levels stay constant over time; and

if $b < 0$, differences in relative income levels increase over time.

$$\frac{y_t^i - y_t}{y_t} = \frac{s_t}{s_0}\left(\frac{y_0^i - y_0}{y_0}\right)$$

Proposition. Suppose that $\delta = 1$, that $0 < k_0 < \hat{k}$, and that $x_t^i > 0$ for all i and all t. Then

if $b > 0$, differences in relative income levels decrease over time;

if $b = 0$, differences in relative income levels stay constant over time; and

if $b < 0$, differences in relative income levels increase over time.

Notice contrast with convergence results for world of closed economies!

What about corner solutions in investment?

If $x_t^i > 0$ for all i and all t, then

$$\frac{k_{t+1}^i - k_{t+1}}{k_{t+1}} = \frac{c_t / k_{t+1}}{c_{t-1} / k_t} \left(\frac{k_t^i - k_t}{k_t} \right) = \frac{z_{t+1}}{z_t} \left(\frac{k_t^i - k_t}{k_t} \right)$$

where $z_t = c_{t-1} / k_t$ and $z_0 = c_0 / \left(\beta r_0 k_0 \right)$.

The sequence z_t has the same monotonicity properties as the sequence $s_t = c_t / y_t$.

Proposition: Suppose that the sequence $s_t = c_t / y_t$ in the equilibrium of the integrated economy is constant or strictly decreasing. There exists an equilibrium where $x_t^i > 0$ for all i and all t.

Proposition: Suppose that the sequence $s_t = c_t / y_t$ in the equilibrium of the integrated economy is strictly increasing. Let

$$\hat{z} = \lim_{t\to\infty} \frac{c_{t-1}}{k_t},$$

and let $\bar{k}_0^{i_{min}} \leq \bar{k}_0^i$, $i = 1,\ldots,n$. If

$$\frac{\hat{z}}{z_0}\left(\frac{\bar{k}_0^{i_{min}} - \bar{k}_0}{\bar{k}_0}\right) \geq -1,$$

then there exists an equilibrium where $x_t^i > 0$ for all i and all t. Otherwise, there is no equilibrium where $x_t^i > 0$ for all i and all t. When there exists an equilibrium with no corner solutions in investment, it is the unique such equilibrium.

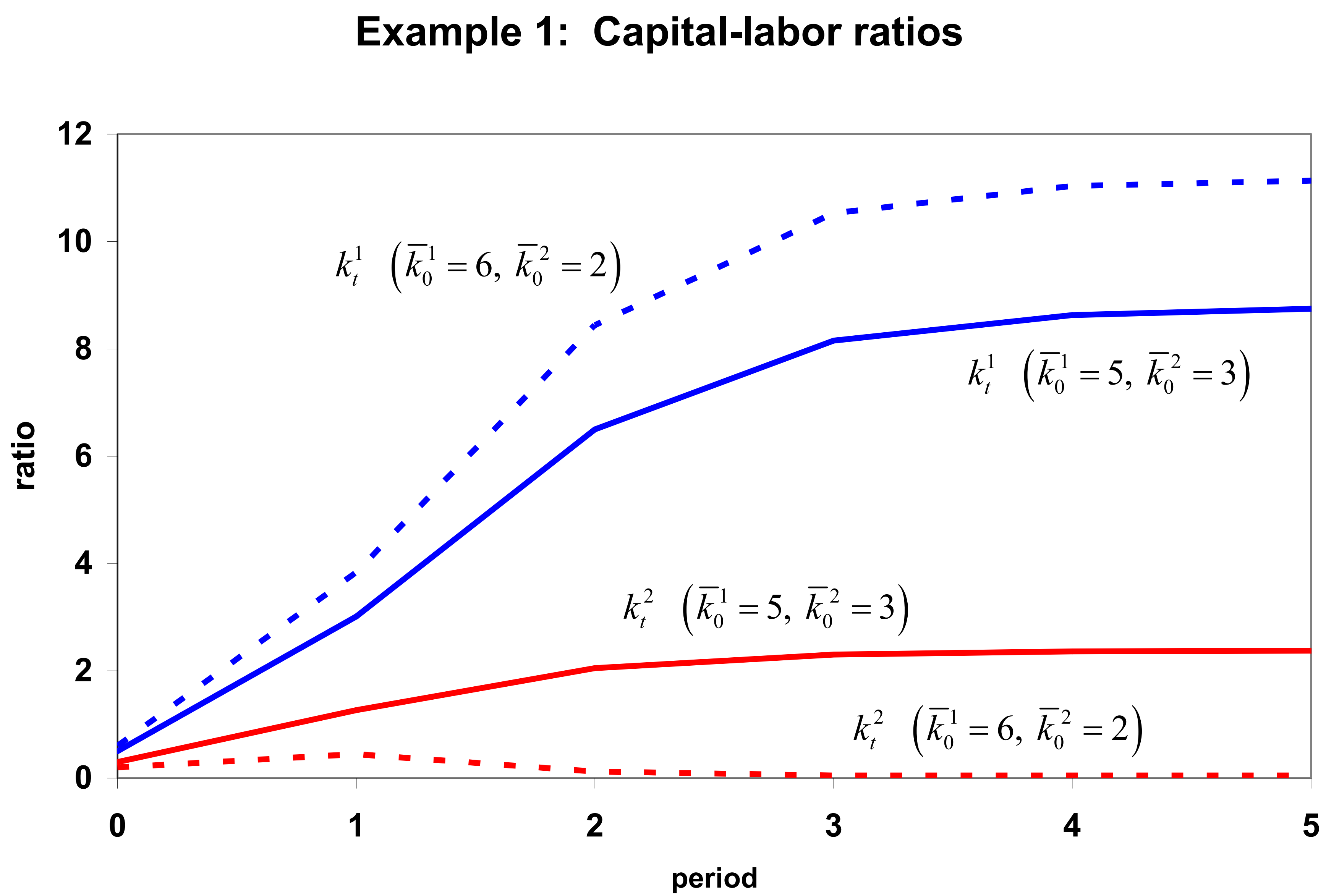
Numerical example 1: Two countries. $\beta = 0.95$, $\delta = 1$, and $L^1 = L^2 = 10$.

$$f(x_1, x_2) = 10\left(0.5x_1^{-0.5} + 0.5x_2^{-0.5}\right)^{-2}.$$

We contrast two different worlds:

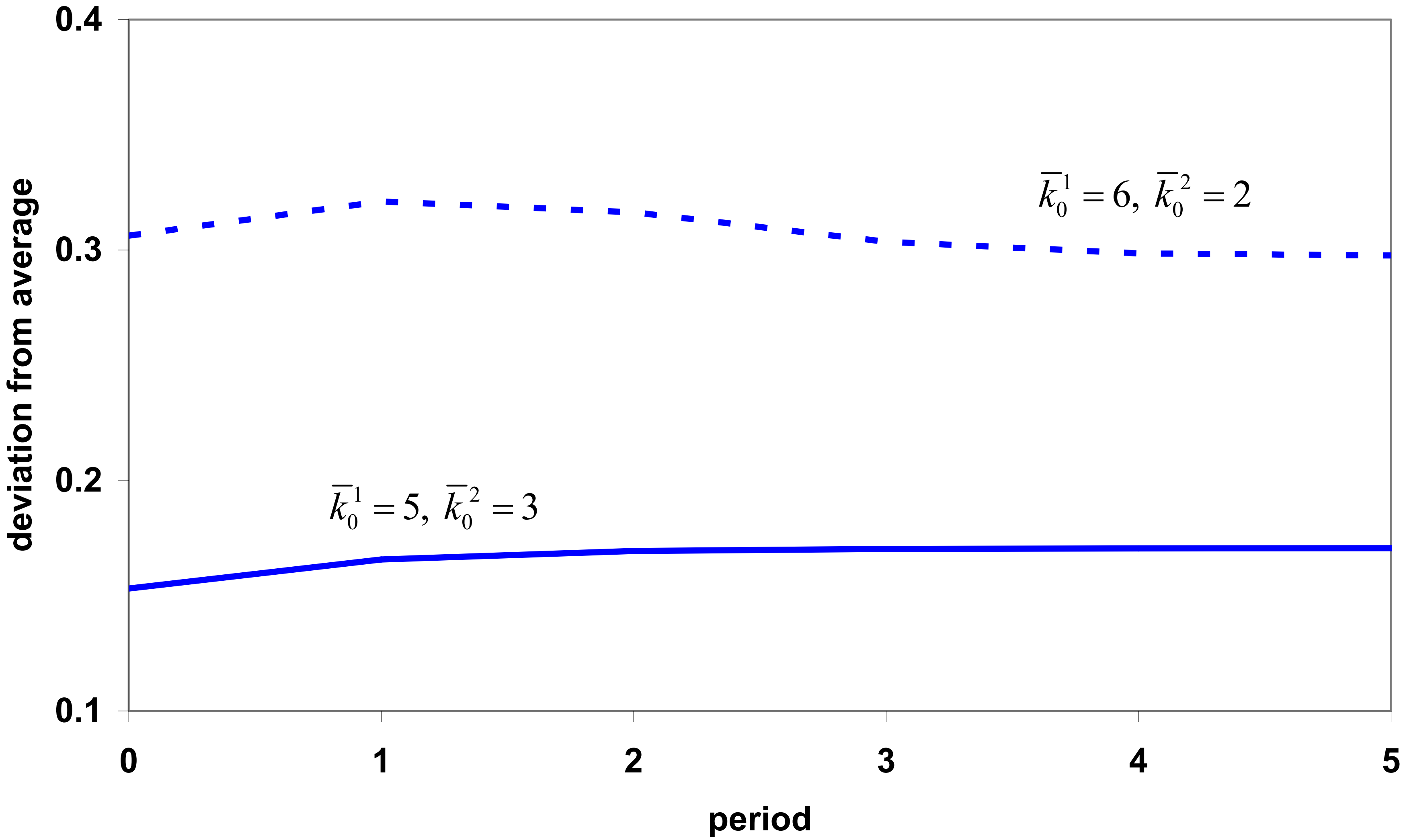
In the first world, $\overline{k}_0^1 = 5$ and $\overline{k}_0^2 = 3$. Here there is an equilibrium with no corner solutions for investment.

In the second world, $\overline{k}_0^1 = 6$ and $\overline{k}_0^2 = 2$. Country 2 has $x_t^i = k_t^i = 0$ starting in period 3.



Example 1: Capital-labor ratios
ratio
period
0
2
4
6
8
10
12
0
1
2
3
4
5
$k_t^1 \quad \left(\bar{k}_0^1 = 6,\ \bar{k}_0^2 = 2\right)$
$k_t^1 \quad \left(\bar{k}_0^1 = 5,\ \bar{k}_0^2 = 3\right)$
$k_t^2 \quad \left(\bar{k}_0^1 = 5,\ \bar{k}_0^2 = 3\right)$
$k_t^2 \quad \left(\bar{k}_0^1 = 6,\ \bar{k}_0^2 = 2\right)$

Example 1: Relative income in country 1



Generalized Ventura Model

$u(c_1, c_2) = v\big(f(c_1, c_2)\big) = \log\big(f(c_1, c_2)\big)$, and f, ϕ_1, and ϕ_2 are general constant-elasticity-of-substitution functions

Define

$$F(k, \ell) = \max\ f(y_1, y_2)$$

$$\text{s.t. } y_1 = \phi_1(k_1, \ell_1)$$

$$y_2 = \phi_2(k_2, \ell_2)$$

$$k_1 + k_2 = k$$

$$\ell_1 + \ell_2 = \ell$$

$$k_j \geq 0,\ \ell_j \geq 0.$$

In Ventura model $F(k, \ell) = f(k, \ell)$.

C. E. S. Model

$$y_1 = \phi_1(k_1, \ell_1) = \theta_1\left(\alpha_1 k_1^b + (1-\alpha_1)\ell_1^b\right)^{1/b}$$

$$y_2 = \phi_2(k_2, \ell_2) = \theta_2\left(\alpha_2 k_2^b + (1-\alpha_2)\ell_2^b\right)^{1/b}$$

$$f(y_1, y_2) = d\left(a_1 y_1^b + a_2 y_1^b\right)^{1/b}$$

(All elasticities of substitution are equal.)

In this case,

$$F(k,\ell) = D\left(A_1 k^b + A_2 \ell^b\right)^{1/b}$$

where

$$A_1 = \frac{\left[\left(a_1\alpha_1\theta_1^b\right)^{\frac{1}{1-b}} + \left(a_2\alpha_2\theta_2^b\right)^{\frac{1}{1-b}}\right]^{1-b}}{\left[\left(a_1\alpha_1\theta_1^b\right)^{\frac{1}{1-b}} + \left(a_2\alpha_2\theta_2^b\right)^{\frac{1}{1-b}}\right]^{1-b} + \left[\left(a_1(1-\alpha_1)\theta_1^b\right)^{\frac{1}{1-b}} + \left(a_2(1-\alpha_2)\theta_2^b\right)^{\frac{1}{1-b}}\right]^{1-b}}$$

$$A_2 = 1 - A_1$$

$$D = d\left\{\left[\left(a_1\alpha_1\theta_1^b\right)^{\frac{1}{1-b}} + \left(a_2\alpha_2\theta_2^b\right)^{\frac{1}{1-b}}\right]^{1-b} + \left[\left(a_1(1-\alpha_1)\theta_1^b\right)^{\frac{1}{1-b}} + \left(a_2(1-\alpha_2)\theta_2^b\right)^{\frac{1}{1-b}}\right]^{1-b}\right\}^{\frac{1}{b}}.$$

The cone of diversification for the integrated economy has the form $\bar{\kappa}_1 k_t \geq k_t^i \geq \bar{\kappa}_2 k_t$.

$$\bar{\kappa}_i = \left(\frac{\alpha_i}{1-\alpha_i}\right)^{\frac{1}{1-b}} \frac{\left(a_1(1-\alpha_1)\theta_1^b\right)^{\frac{1}{1-b}} + \left(a_2(1-\alpha_2)\theta_2^b\right)^{\frac{1}{1-b}}}{\left(a_1\alpha_1\theta_1^b\right)^{\frac{1}{1-b}} + \left(a_2\alpha_2\theta_2^b\right)^{\frac{1}{1-b}}}.$$

The cone of diversification for the integrated economy has the form $\bar{\kappa}_1 k_t \geq k_t^i \geq \bar{\kappa}_2 k_t$.

$$\bar{\kappa}_i = \left(\frac{\alpha_i}{1-\alpha_i}\right)^{\frac{1}{1-b}} \frac{\left(a_1(1-\alpha_1)\theta_1^b\right)^{\frac{1}{1-b}} + \left(a_2(1-\alpha_2)\theta_2^b\right)^{\frac{1}{1-b}}}{\left(a_1\alpha_1\theta_1^b\right)^{\frac{1}{1-b}} + \left(a_2\alpha_2\theta_2^b\right)^{\frac{1}{1-b}}}.$$

This is not the cone of diversification when factor prices are not equalized.

$$\kappa_1(p_2/p_1) = \left(\frac{\alpha_1}{1-\alpha_1}\right)^{\frac{1}{1-b}} \left[\frac{(1-\alpha_2)^{\frac{1}{1-b}}(\theta_2 p_2/p_1)^{\frac{b}{1-b}} - (1-\alpha_1)^{\frac{1}{1-b}}\theta_1^{\frac{b}{1-b}}}{\alpha_1^{\frac{1}{1-b}}\theta_1^{\frac{b}{1-b}} - \alpha_2^{\frac{1}{1-b}}(\theta_2 p_2/p_1)^{\frac{b}{1-b}}}\right]^{\frac{1}{b}}$$

$$\kappa_1(p_2/p_1) = \left[\left(\frac{\alpha_2}{1-\alpha_2}\right)\left(\frac{1-\alpha_1}{\alpha_1}\right)\right]^{\frac{1}{1-b}} \kappa_2(p_2/p_1).$$

Cobb-Douglas Model

$$y_1 = \phi_1(k_1, \ell_1) = \theta_1 k_1^{\alpha_1} \ell_1^{1-\alpha_1}$$

$$y_2 = \phi_2(k_2, l_2) = \theta_2 k_2^{\alpha_2} \ell_2^{1-\alpha_2}$$

$$f(y_1, y_2) = d y_1^{a_1} y_2^{a_2}$$

(This is the special case of the C.E.S. model where $b = 0$.)

In this case

$$F(k,\ell) = Dk^{A_1}\ell^{A_2}$$

where

$$A_1 = a_1\alpha_1 + a_2\alpha_2$$

$$A_2 = 1 - A_1$$

$$D = \frac{d\left[\theta_1 a_1 \alpha_1^{\alpha_1}(1-\alpha_1)^{1-\alpha_1}\right]^{a_1}\left[\theta_2 a_2 \alpha_2^{\alpha_2}(1-\alpha_2)^{1-\alpha_2}\right]^{a_2}}{A_1^{A_1} A_2^{A_2}}$$

$$\bar{\kappa}_i = \left(\frac{\alpha_i}{1-\alpha_i}\right)\frac{A_2}{A_1}.$$

Proposition: In the Cobb-Douglas model with $\delta = 1$, suppose that factor price equalization occurs at period T. Then factor price equalization occurs at all $t \geq T$. Furthermore, the equilibrium capital stocks can be solved for as

$$k_t^i = \gamma^i k_t$$

where $\gamma^i = k_T^i / k_T$ and $k_{t+1} = \beta A_1 D k_t^{A_1}$ for $t \geq T$.

Proposition: In the C.E.S. model with $\delta = 1$, suppose that the sequence $s_t = c_t / y_t$ in the equilibrium of the integrated economy is weakly decreasing. Suppose that factor price equalization occurs in period T. Then there exists an equilibrium in which factor price equalization occurs at all $t \geq T$. Furthermore, this equilibrium is the only such equilibrium.

Proposition: In the C.E.S. model with $\delta = 1$, suppose that the sequence $s_t = c_t / y_t$ in the equilibrium of the integrated economy is strictly increasing. Again let $z_t = c_{t-1} / k_t$, $z_0 = c_0 /(\beta r_0 k_0)$, and $\hat{z} = \lim_{t\to\infty} c_{t-1} / k_t$. Let $\bar{k}_0^{i_{min}} \le \bar{k}_0^i \le \bar{k}_0^{i_{max}}$, $i = 1,\dots,n$. If

$$\frac{\hat{z}}{z_0}\left(\frac{\bar{k}_0^{i_{min}} - \bar{k}_0}{\bar{k}_0}\right) \ge \kappa_2 - 1,\ \frac{\hat{z}}{z_0}\left(\frac{\bar{k}_0^{i_{max}} - \bar{k}_0}{\bar{k}_0}\right) \le \kappa_1 - 1,$$

then there exists an equilibrium with factor price equalization in every period. If, however, either of these conditions is violated, there is no equilibrium with factor price equalization in every period. When there exists an equilibrium with factor price equalization in every period, it is the unique such equilibrium.

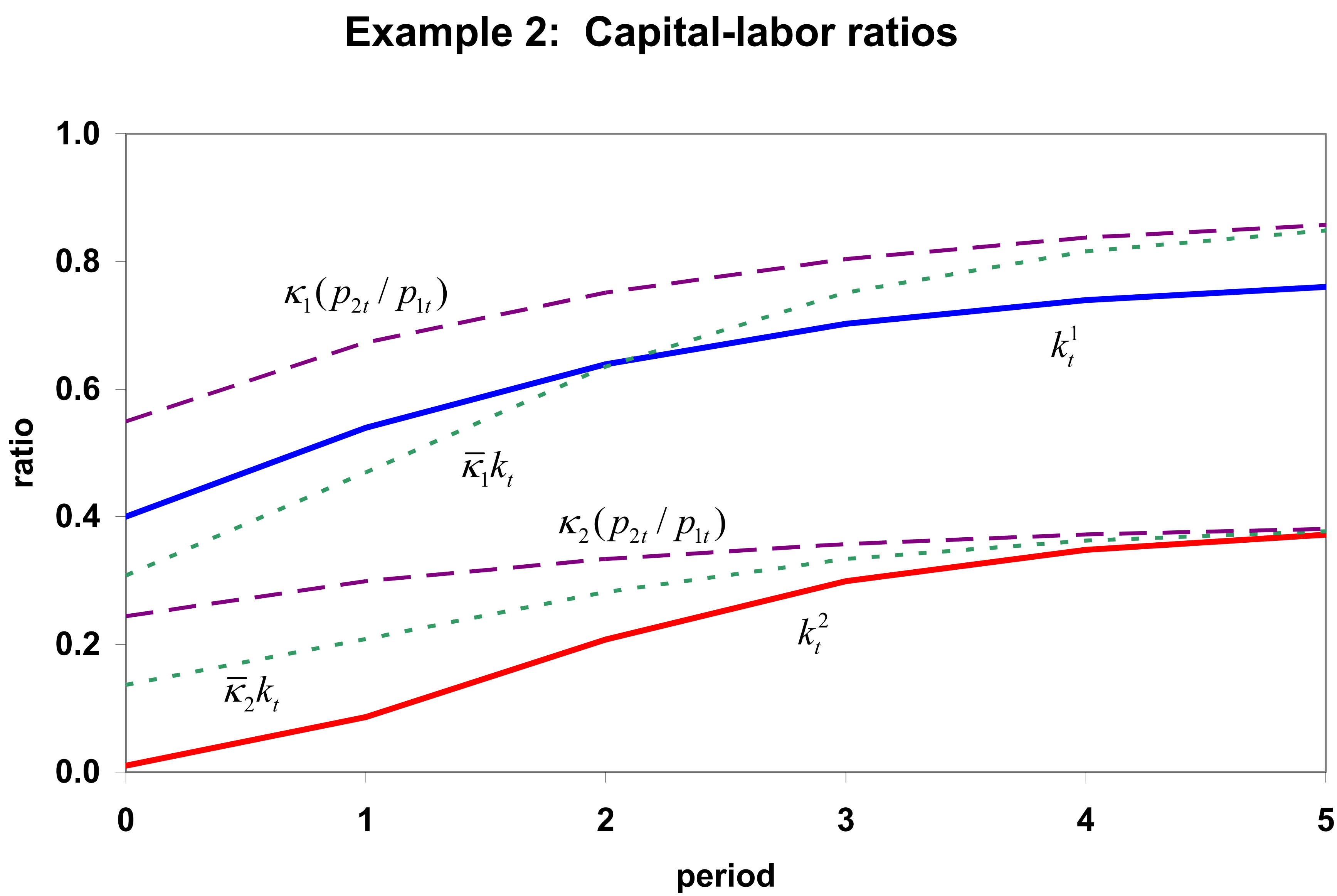
Numerical example 2: Two countries. $\beta = 0.95$, $\delta = 1$, and $L^1 = L^2 = 10$.

$$\phi_1(k,\ell) = 10k^{0.6}\ell^{0.4}$$

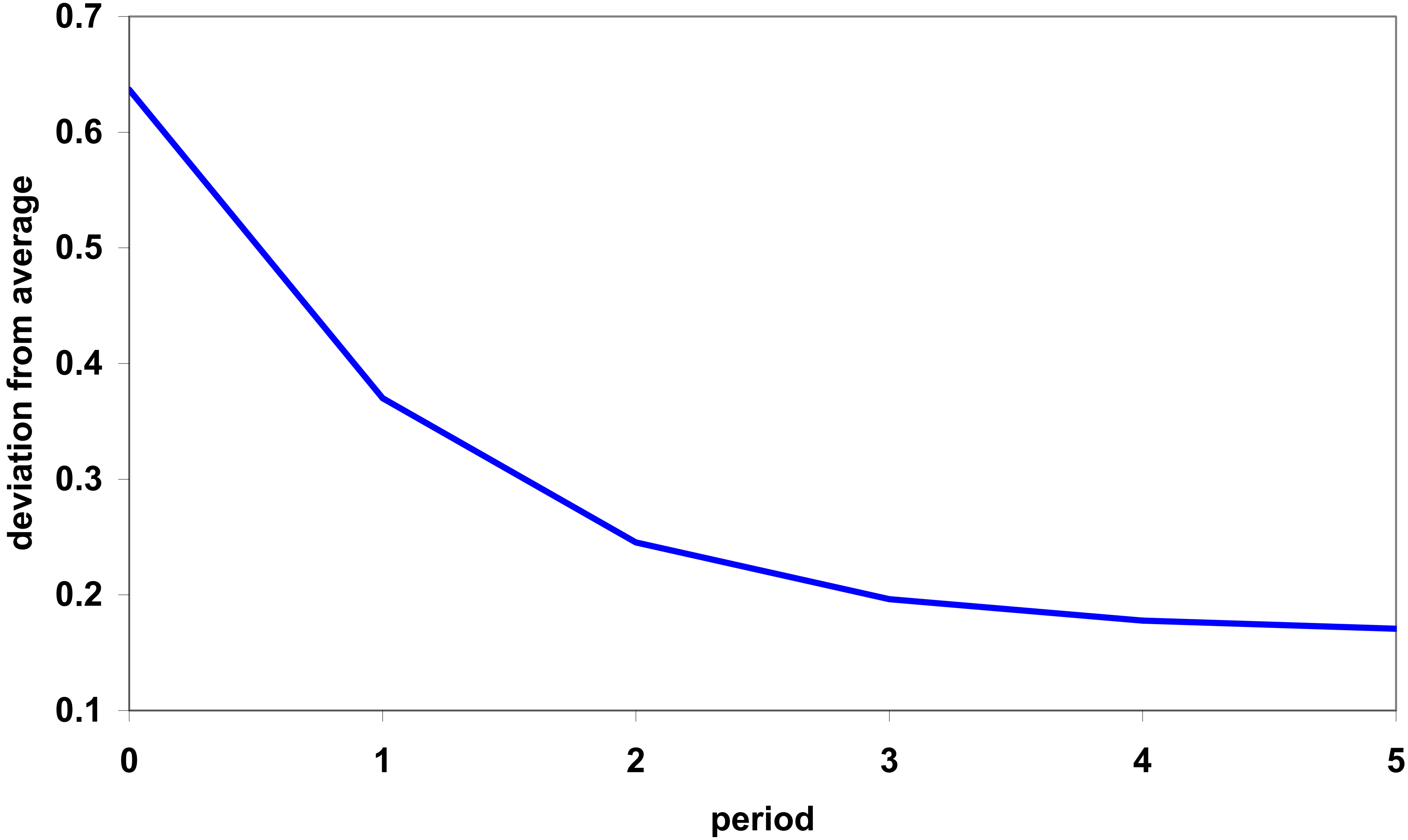
$$\phi_2(k,\ell) = 10k^{0.4}\ell^{0.6}$$

$$f(x_1,x_2) = x_1^{0.5}x_2^{0.5}$$

$\overline{k}_0^1 = 4$, $\overline{k}_0^2 = 0.1$.


Example 2: Capital-labor ratios
1.0
0.8
0.6
0.4
0.2
0.0
ratio
0
1
2
3
4
5
period
$\kappa_1(p_{2t}/p_{1t})$
$\bar{\kappa}_1 k_t$
k_t^1
$\kappa_2(p_{2t}/p_{1t})$
k_t^2
$\bar{\kappa}_2 k_t$

Example 2: Relative income in country 1



Numerical example 3: Two countries. $\beta = 0.95$, $\delta = 1$, and $L^1 = L^2 = 10$.

$$\phi_1(k,\ell) = 10\left(0.8k^{-0.5} + 0.2\ell^{-0.5}\right)^{-2}$$

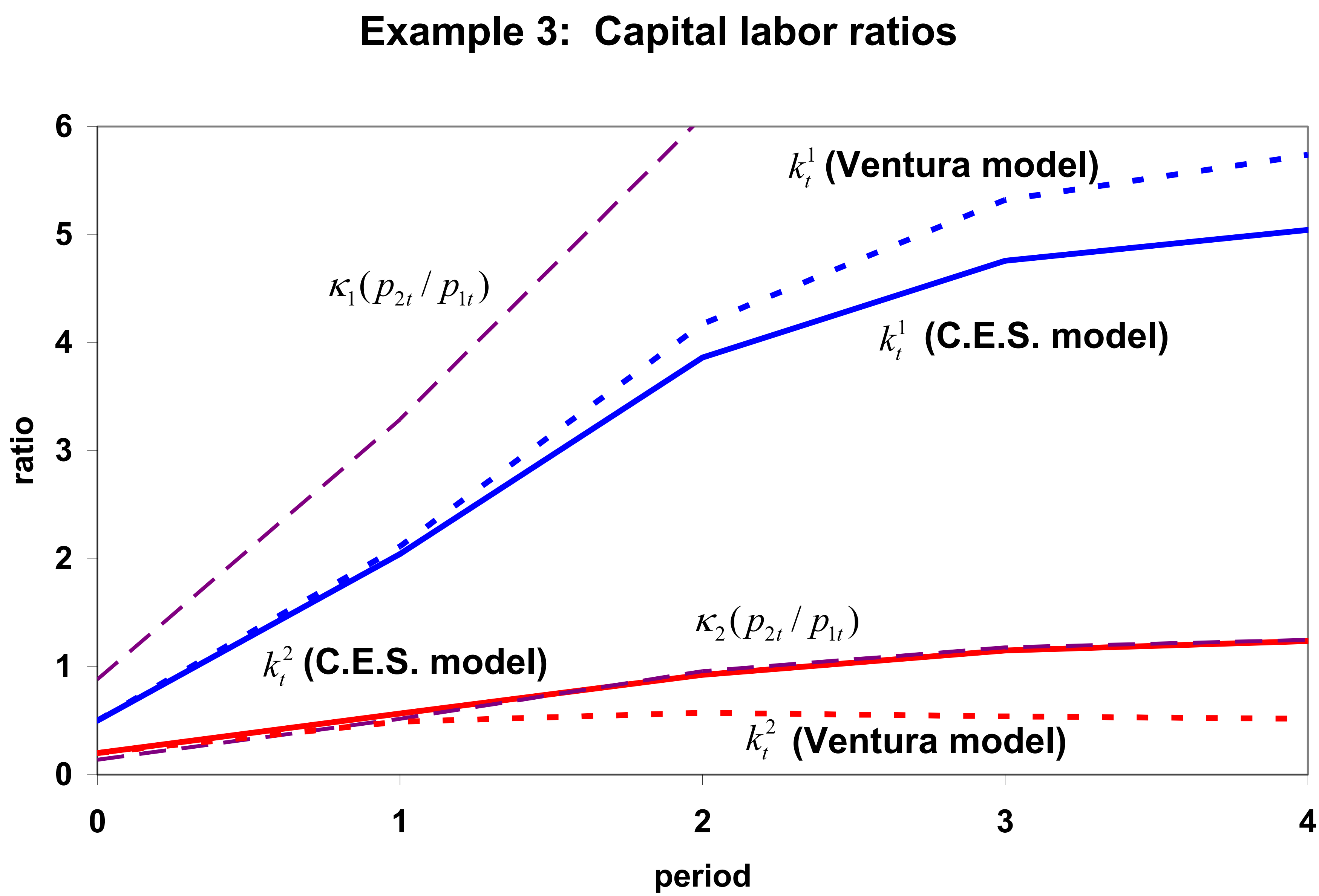
$$\phi_2(k,\ell) = 10\left(0.2k^{-0.5} + 0.8\ell^{-0.5}\right)^{-2}$$

$$f(x_1,x_2) = \left(0.5x_1^{-0.5} + 0.5x_2^{-0.5}\right)^{-2}$$

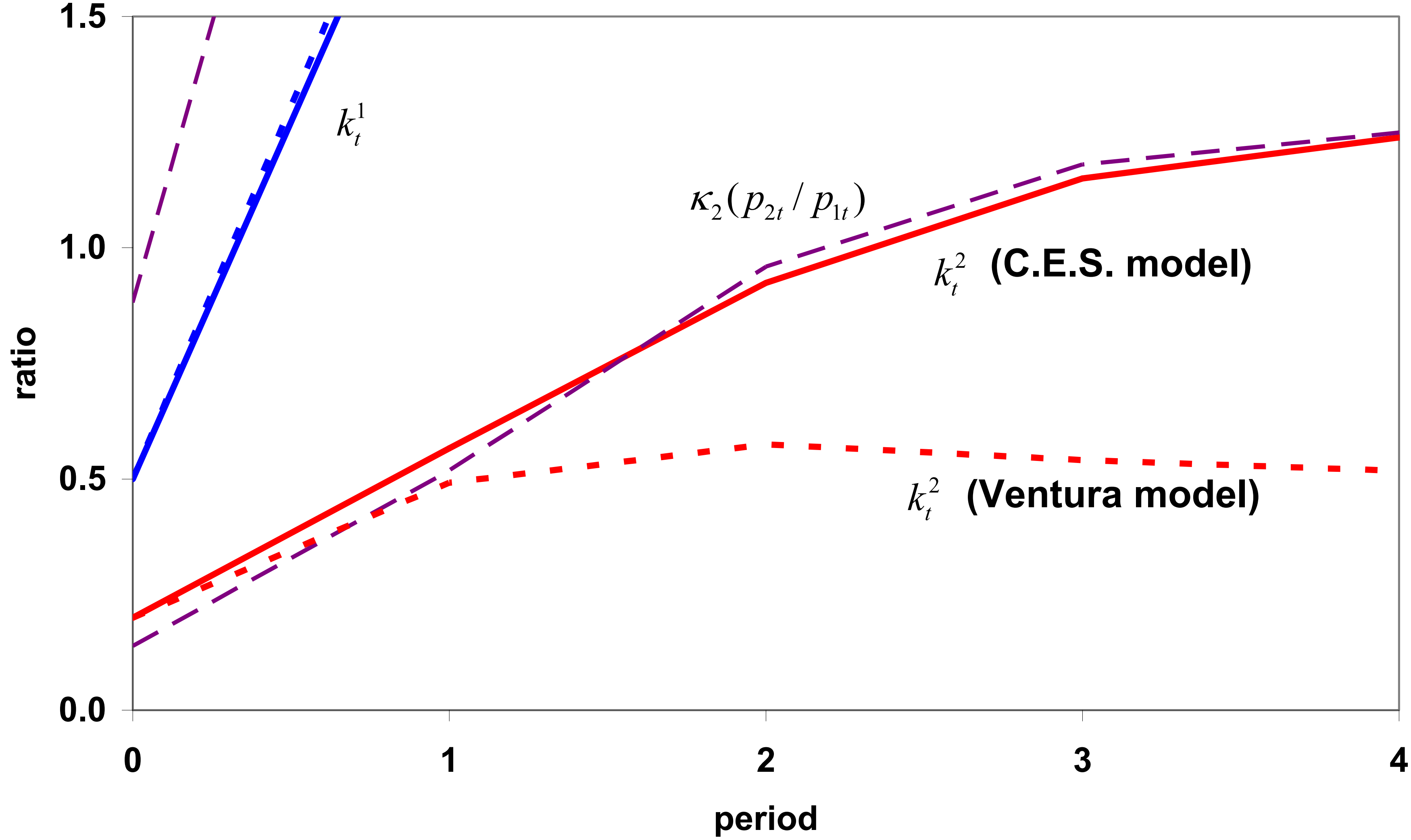
$$\bar{k}_0^1 = 5\ ,\bar{k}_0^2 = 2.$$

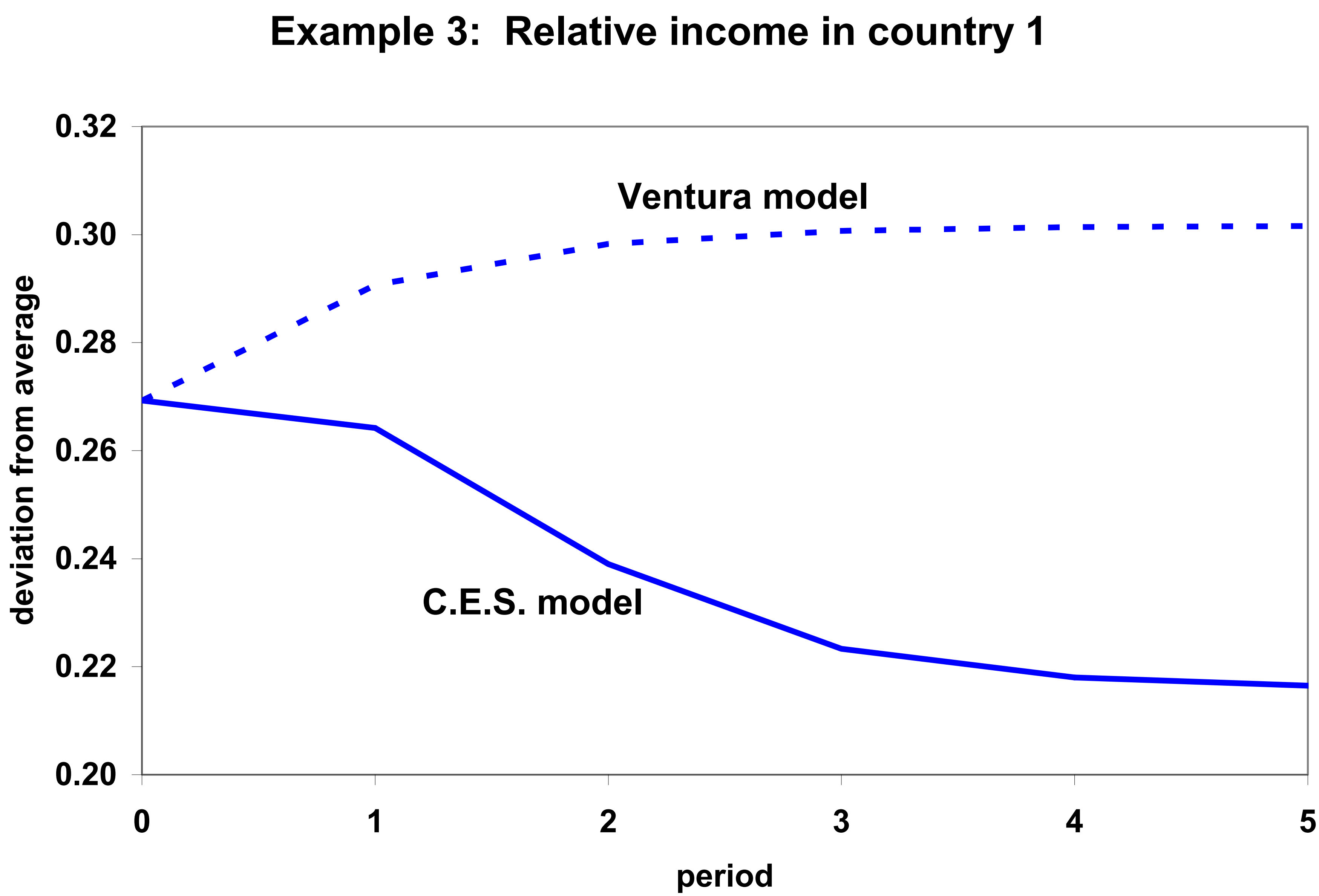
Contrast with the Ventura model with the same integrated equilibrium:

$$f(x_1,x_2) = 5.7328\left(0.5x_1^{-0.5} + 0.5x_2^{-0.5}\right)^{-2}.$$


Example 3: Capital labor ratios
k_t^1 (Ventura model)
$\kappa_1(p_{2t}/p_{1t})$
k_t^1 (C.E.S. model)
$\kappa_2(p_{2t}/p_{1t})$
k_t^2 (C.E.S. model)
k_t^2 (Ventura model)
ratio
period
0
1
2
3
4
5
6

Example 3: Capital labor ratios (detail)





Example 3: Relative income in country 1
Ventura model
C.E.S. model
deviation from average
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0
1
2
3
4
5
period

6. Favorable changes in the terms of trade and/or reductions in tariffs make it easier to import intermediate goods. Although this is often interpreted as an increase in productivity, it does not show up as such in productivity measures that use real GDP as a measure of output.

T. J. Kehoe and K. J. Ruhl, "Are Shocks to the Terms of Trade Shocks to Productivity?" Federal Reserve Bank of Minneapolis, 2007.

A deterioration in the terms of trade makes it expensive for an economy to import intermediate goods.

We can think of international trade as part of the production technology. Exports are inputs, imports are outputs. A deterioration in the terms of trade corresponds to a negative technology shock.

Can this negative "technology shock" account for the drop in TFP during the crisis?

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We can think of international trade as part of the production technology. Exports are inputs, imports are outputs. A deterioration in the terms of trade corresponds to a negative technology shock.

Can this negative "technology shock" account for the drop in TFP during the crisis?

No!

Standard national income accounting (SNA, NIPA) implies that terms of trade shocks have no first-order effects on real output (GDP, GNP)

A simple model with intermediate goods

Labor

$$\ell_t = \overline{\ell}$$

Final good

$$y_t = f(\overline{\ell}, m_t)$$

Intermediate good

$$m_t = \frac{x_t}{a_t}$$

Feasibility

$$c_t + x_t = y_t$$

Real GDP

$$c_t = y_t - x_t = f(\overline{\ell}, m_t) - a_t m_t$$

Competitive economy solves

$$\max_{m_t} f(\bar{\ell}, m_t) - am_t$$

$$f_m(\bar{\ell}, m(a_t)) \equiv a_t$$

$$f_{mm}(\bar{\ell}, m(a_t))m'(a_t) = 1$$

$$m'(a_t) = \frac{1}{f_{mm}(\bar{\ell}, m(a_t))} < 0$$

How does real GDP change with an increase in a — a negative shock to the intermediate goods producing technology?

$$Y(a_t) \equiv f(\bar{\ell}, m(a_t)) - a_t m(a_t)$$

$$Y'(a_t) = f_m(\bar{\ell}, m(a_t))m'(a_t) - a_t m'(a_t) - m(a_t) = -m(a_t) < 0$$

A model with international trade

Suppose now that

m is imported intermediate inputs,

x is exports,

$p = a$ is terms of trade (real exchange rate)

Balanced trade

$$p_t m_t = x_t$$

Real GDP

$$c_t + x_t - p_0 m_t = y_t - p_0 m_t = f(\bar{\ell}, m_t) - p_0 m_t$$

where p_0 is price of imports in the base year.

Competitive economy continues to solve

$$\max_{m_t} f(\bar{\ell}, m_t) - p_t m_t$$

$$f_m(\bar{\ell}, m(p_t)) \equiv p_t$$

$$m'(p_t) = \frac{1}{f_{mm}(\bar{\ell}, m(p_t))} < 0$$

How does real GDP change with an increase in p_t — a deterioration in the terms of trade (depreciation in the real exchange rate)?

$$Y(p_t) \equiv f(\bar{\ell}, m(p_t)) - p_0 m(p_t)$$

$$Y'(p_t) = f_m(\bar{\ell}, m(p_t)) m'(p_t) - p_0 m'(p_t) = (p_t - p_0) m'(p_t)$$

$$p_0 \approx p_t \;\Rightarrow\; Y'(p_t) \approx 0$$

Alternative accounting concepts

- Diewert and Morrison (1974, 1986)
- Kohli (1983, 1996)
- U.S. Bureau of Economic Analysis (Command Basis GDP)
- United Nations Statistics Division (Gross National Income)
- GNP, GDP (SNA, NIPA) do not.

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Terms of trade shocks are worse than you think!

Extensions

Chain weighted price indices

Changes in tariffs

Endogenous labor

7. In models with heterogeneous firms (for example, Melitz, Chaney), trade liberalization can cause resources to shift from less productive firms to more productive firms. Although this is often interpreted as an increase in productivity, it does not show up as such in productivity measures that use real GDP as a measure of output.

M. J. Gibson, "Trade Liberalization, Reallocation, and Productivity," University of Minnesota, 2006. http://www.econ.umn.edu/~tkehoe/papers/Gibson.pdf.

Some countries experience aggregate productivity increases following trade liberalization

What is the economic mechanism through which this occurs?

Does trade liberalization increase aggregate productivity through reallocation toward more productive firms or through productivity increases at individual firms?

Reallocation mechanism

Technology of each firm is fixed

Trade liberalization results in a reallocation of resources:

- The least efficient firms exit

- Resources are moved toward more efficient firms, particularly exporters

Main findings

Reallocation following trade liberalization has no first-order effect on productivity, but it matters for welfare

Productivity gains must primarily come from firm-level productivity increases

Gibson studies a technology adoption mechanism in which firms can upgrade to a better technology, but it is costly to do so. Trade liberalization encourages technology adoption.

Model

I symmetric countries, each with an *ad valorem* tariff on imports

Monopolistically competitive firms that are heterogeneous in technological efficiency

Sunk cost of entering export markets — only the most efficient firms export

Fixed cost of production — not all firms choose to operate

No aggregate uncertainty

Consumer's problem

$$\max \sum_{t=0}^{\infty} \beta^t \log\left(\int_{z \in Z_t} c_t(z)^{\rho} \, dz \right)^{1/\rho}$$

$$\text{s.t.} \quad \int_{z \in Z_t^d} p_t(z) c_t(z) \, dz + (1+\tau_t) \int_{z \in Z_t^x} p_t(z) c_t(z) \, dz = \bar{N} + \Pi_t + \mathrm{T}_t$$

Aggregation

Ideal real income index:

$$C_t = \left(\int_{z \in Z_t} c_t(z)^{\rho} \, dz \right)^{1/\rho}$$

Ideal price index:

$$P_t = \left(\int_{z \in Z_t^d} p_t(z)^{\frac{-\rho}{1-\rho}} \, dz + (1+\tau_t)^{\frac{-\rho}{1-\rho}} \int_{z \in Z_t^x} p_t(z)^{\frac{-\rho}{1-\rho}} \, dz \right)^{\frac{-(1-\rho)}{\rho}}$$

Budget constraint again:

$$P_t C_t = \bar{N} + \Pi_t + \mathrm{T}_t$$

Demand functions

Firms take the consumer's demand functions as given

Demand for domestically produced goods:

$$\tilde{c}_t^d(p) = \left(\frac{P_t}{p}\right)^{\frac{1}{1-\rho}} C_t$$

Demand for imported goods:

$$\tilde{c}_t^x(p) = \left(\frac{P_t}{(1+\tau_t)p}\right)^{\frac{1}{1-\rho}} C_t$$

Firms: Timing within a period

Entrants learn their efficiencies

Each firm decides whether to operate or exit — producing requires paying a fixed cost of f^p units of labor

Non-exporters decide whether to pay the sunk cost of entering export markets, f^x units of labor

After producing, each firm faces exogenous probability of death δ

Technologies

A firm of type a has the increasing-returns technology

$$y(n;a) = \max\left[a\left(n - f^p\right), 0\right]$$

$a \in [1,\infty)$ is the firm's technology draw from Pareto distribution
$F(a) = 1 - a^{-\eta}$

f^p is the fixed cost, in units of labor, of producing

Firm's static problem: Maximize period profits

Non-exporters:

$$\pi_t^d(a) = \max_{p,n} p\tilde{c}_t^d(p) - n$$

$$\text{s.t. } a\left(n - f^p\right) = \tilde{c}_t^d(p)$$

Exporters:

$$\pi_t^x(a) = \max_{p,n} p\left(\tilde{c}_t^d(p) + (I-1)\tilde{c}_t^x(p)\right) - n$$

$$\text{s.t. } a\left(n - f^p\right) = \tilde{c}_t^d(p) + (I-1)\tilde{c}_t^x(p)$$

Prices

The profit-maximizing price is a constant markup over marginal cost:

$$p(a) = \frac{1}{\rho a}$$

The price of a good is inversely related to the efficiency with which it is produced

Exporter's dynamic problem

$$v_t^x(a) = \max\left[0,\ \pi_t^x(a) + \frac{1-\delta}{1+r_{t+1}} v_{t+1}^x(a)\right]$$

Non-exporter's dynamic problem

$$v_t^d(a) = \max\left[0,\ \pi_t^d(a) + \frac{1-\delta}{1+r_{t+1}} \max\left[v_{t+1}^d(a), v_{t+1}^x(a) - \frac{1+r_{t+1}}{1-\delta} f^x\right]\right]$$

Outer maximization: Whether to operate

Inner maximization: Whether to devote f^x units of labor to enter export markets

Firm entry

There is free entry of firms, and firms enter as non-exporters

The cost of a technology draw from probability distribution F is f^e units of labor

The measure of draws taken, e_t, is determined endogenously through a free-entry condition:

$$\frac{1}{1+r_{t+1}}\int v_{t+1}^{d}\left(a\right)F\left(da\right)-f^{e}\leq 0,\ \ =0 \text{ if } e_t>0$$

The inequality reflects the constraint that $e_t \geq 0$

Distributions of firms by efficiency

Suppose that at the beginning of period t the distribution of non-exporters is m_t^d and the distribution of exporters is m_t^x

To obtain the distributions of firms that choose to operate, apply the decision rules:

$$\mu_t^x(a) = \int_1^a \chi_t^x(\alpha) m_t^x(d\alpha)$$

$$\mu_t^d(a) = \int_1^a \chi_t^d(\alpha) m_t^d(d\alpha)$$

Distributions evolve in response to firm entry, e_t and changes in export status, χ_t^e

Labor market clearing

The supply of labor is fixed at $\bar{N}$ and is allocated among 3 activities: production, entering export markets, and entering the domestic market

$$\sum_s \int \left(n_t^d(a)\mu_t^d(da) + n_t^x(a)\mu_t^x(da) + f^x \chi_t^e(a)\mu_t^d(da) \right) + f^e e_t = \bar{N}.$$

Measuring productivity

Labor productivity in the data is a measure of real value added per worker or per hour

Standard way of calculating real value added is to use base-period prices

Measuring real value added per worker

Value added at current prices:

$$y_t = \int_{z \in Z_t^d} p_t(z)\, y_t(z)\, dz$$

Value added at base-period (period-0) prices:

$$Y_t = \int_{z \in Z_t^d} p_0(z)\, y_t(z)\, dz$$

Real value added per worker is $Y_t / \bar{N}$

What if a good was not produced in the base period?

This is an issue in the data as well

The standard recommendation for obtaining a proxy for the base-period price is to deflate the current price by the price index for a basket of goods that were produced in both periods, say $\tilde{Z}$:

$$\tilde{P}_t = \frac{\int_{\tilde{Z}} p_t(z)\, y_0(z)\, dz}{\int_{\tilde{Z}} p_0(z)\, y_0(z)\, dz}$$

Proxy for the period-0 price of a good not produced in period 0:

$$p_0(z) = \frac{p_t(z)}{\tilde{P}_t}$$

Measuring social welfare

Ideal real income index:

$$\frac{\bar{N} + \Pi_t + \mathrm{T}_t}{P_t} = C_t = \left(\int_{z \in Z_t} c_t(z)^{\rho} \, dz \right)^{1/\rho}$$

The ideal price index P_t takes into account changes in variety and the consumer's elasticity of substitution — in contrast to price indices in the data

To what extent can reallocation following trade liberalization account for long-term productivity gains?

To determine the long-term effects of trade liberalization, we compare stationary equilibria of the model

two versions of the model:

Static version with $\beta \to 1$ (similar to Melitz (2003)): analytical result

Dynamic version with $0 < \beta < 1$: illustrative numerical example

Static model: An analytical finding

Proposition: In a stationary equilibrium with $\beta \to 1$, real value added per worker does not depend on the level of the tariff

To see why:

With $\beta \to 1$, $\Pi = 0$, so the budget constraint gives

$$\int_{z \in Z_t^d} p_t(z) c_t(z) dz + \int_{z \in Z_t^x} p_t(z) c_t(z) dz = \bar{N}$$

The balanced trade condition is

$$\int_{z \in Z_t^d} p_t(z) \left(y_t(z) - c_t(z) \right) dz = \int_{z \in Z_t^x} p_t(z) c_t(z)$$

Add them together to get

$$\int_{z \in Z_t^d} p_t(z) y_t(z) dz = \bar{N}$$

So value added at current prices is constant, does not depend on τ

What about base-period prices? Without technology adoption, the price of each good in the economy is constant: $p(z;a) = 1/(\rho a)$

So base-period prices are equal to current prices and the prices of new goods do not get deflated

Result:

$$Y_t = \int_{z \in Z_t^d} p_0(z) y_t(z) dz = \int_{z \in Z_t^d} p_t(z) y_t(z) dz = \bar{N}$$

Intuition for the result

Reallocation following trade liberalization has no long-term effect on measured productivity

Why? Two factors:

Prices — they are inversely related to the efficiency with which a good is produced

General equilibrium effects — changes in the real wage (partial equilibrium analysis would predict a substantial increase in measured productivity)

Parameterization for illustrative numerical experiment

$\bar{N} = 1$	Normalization
$\rho = 0.5$	Elasticity of substitution of 2 (Ruhl 2003)
$\eta = 1.5$	
$\delta = 0.05$	
$f^e = 1$	
f^x	20 percent of firms export initially
f^p	Efficiency cutoff for operating is 1 initially

Illustrative numerical experiment in the static model

$\beta \to 1$

Policy experiment: Eliminate a 10 percent tariff between 2 countries

Compare stationary equilibria to assess long-term effects of trade liberalization:

Percent change in measured productivity	0.0
Percent change in welfare	0.5

A note on the welfare increase

The increase in welfare following trade liberalization is not due to an increase in variety — the measure of varieties available to the consumer decreases

Reallocation toward more efficient firms drives the welfare increase

This is in sharp contrast to trade models with homogeneous firms, in which the increase in welfare is driven by an increase in variety

Main point: Reallocation matters for welfare but not for measured productivity

Illustrative numerical experiment in the dynamic model

To what extent can the fully dynamic model account for measured productivity gains?

$\beta = 0.96$ Real interest rate of 4 percent

Same numerical experiment:

Percent change in measured productivity	0.7
Percent change in welfare	1.8