The Elasticity of Trade: Estimates and Evidence

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Big Picture

The elasticity of trade with respect to trade frictions, θ, is critical to any quantitative analysis.

Depending on this elasticity...

- The "size" of the U.S.-Canada border, Anderson and Van Wincoop (2003)
- Tariff reductions role in growth of world trade, Yi (2003)
- Welfare gains in many trade models, Arkolakis, Costinot, and Rodriguez-Clare (2009)

Eaton and Kortum (2002): innovative approach to recover trade frictions and estimate θ. Their estimate is widely referenced in quantitative applications.

Our Paper...

Our paper:

- Prove the EK (2002) estimate is biased and provide monte carlo evidence that the bias is substantial.
- New method to estimate θ under same data requirements as EK (2002) that resolves this bias.
- New estimate for 123 countries that comprise 98% of world GDP
- These results $\Rightarrow$ **welfare cost of autarky is twice as high with our θ.**

Model: Eaton and Kortum (2002)

N countries indexed by i. A continuum of tradable goods $x(j)$, $j \in [0,1]$.

- Consumer preferences over goods

$$U_i = \left[\int_0^1 x_i(j)^{\frac{\rho-1}{\rho}} dj \right]^{\frac{\rho}{\rho-1}}.$$

- Firms from country i can supply $x(j)$ to country n at price

$$p_{ni}(j) = \tau_{ni} \frac{w_i}{z_i(j)}.$$

- Productivity, $z_i(j)$, is drawn from a Fréchet distribution

$$F_i(z_i) = \exp\left(-T_i z_i^{-\theta} \right),$$

where θ is the key parameter of interest.

Model: Eaton and Kortum (2002)

Expenditure share of *i* goods in *n*

$$\frac{X_{ni}}{X_n} = \frac{T_i(\tau_{ni} w_i)^{-\theta}}{\sum_{k=1}^{N} T_k(\tau_{nk} w_k)^{-\theta}}.$$

θ controls ...

- dispersion in productivity draws,
- response of trade to changes in trade costs,
- welfare gains from trade.

Model: Eaton and Kortum (2002)

Expenditure share of i goods in n

$$\frac{X_{ni}}{X_n} = \frac{T_i(\tau_{ni}w_i)^{-\theta}}{\sum_{k=1}^{N} T_k(\tau_{nk}w_k)^{-\theta}}.$$

Many CES trade models generate this exact same relationship: Krugman (1980), Anderson and van Wincoop (2003), Melitz (2002) à la Chaney (2008)

- Across all these models the EK (2002) estimate of θ is widely referenced in quantitative applications.

EK (2002) Approach to Estimating θ

They derive the relationship

$$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \left(\frac{P_i \tau_{ni}}{P_n}\right)^{-\theta}$$

where:

$$P_n = \gamma \left[\sum_{k=1}^{N} T_k (\tau_{nk} w_k)^{-\theta}\right]^{-\frac{1}{\theta}},$$

γ is constant.

EK (2002) Approach to Estimating θ

Take logs and run the regression. . .

$$\log\left(\frac{X_{ni}/X_n}{X_{ii}/X_i}\right) = -\beta\left(\log\tau_{ni} + \log P_i - \log P_n\right)$$

Key issues

- How to approximate $\log\tau_{ni}$?
- Given the approximation, does the expected value of $\beta = \theta$?

Approximating the Trade Friction

Suppose we see prices of good ℓ across countries.

If we know that good ℓ in country n came from i, then

$$\frac{p_n(\ell)}{p_i(\ell)} = \tau_{ni}.$$

If we do not know where good ℓ came from, following inequality must hold:

$$p_n(\ell) \leq \tau_{ni} p_i(\ell).$$

Why? If $p_n(\ell) > \tau_{ni} p_i(\ell)$, then one could have imported ℓ at a lower price.

Approximating the Trade Friction

The inequality $p_n(\ell) \leq \tau_{ni} p_i(\ell)$ puts a lower bound on the unknown trade cost

$$\frac{p_n(\ell)}{p_i(\ell)} \leq \tau_{ni}$$

Seeing L goods improves this bound

$$\max_{\ell \in L} \left\{ \frac{p_n(\ell)}{p_i(\ell)} \right\} \leq \tau_{ni}$$

EK (2002) Approach to Estimating θ

Their estimatimator...

$$\hat{\beta} = -\frac{\sum_n \sum_i \log\left(\frac{X_{ni}/X_n}{X_{ii}/X_i}\right)}{\sum_n \sum_i \left(\log \hat{\tau}_{ni} + \log \hat{P}_i - \log \hat{P}_n\right)}$$

Variables in the denominator are...

- $\log \hat{\tau}_{ni} = \max_{\ell \in L} \{\log p_n(\ell) - \log p_i(\ell)\}$
- $\hat{P}_i = \frac{1}{L} \sum_{\ell=1}^{L} p_i(\ell)$
- $p_i(\ell)$ are r.v.'s sampled from the equilibrium distribution of prices.

Proposition 1: EK (2002) Estimator is Biased Upward

If a sample of L prices is available, then

$$E(\hat{\beta}) = -\theta \frac{\sum_n \sum_i \log\left(\frac{X_{ni}/X_n}{X_{ii}/X_i}\right)}{\sum_n \sum_i (\Psi_{ni}(L;\mathbf{S}) - \Omega_{ni})} \; > \; \theta$$

where:

$$\Psi_{ni}(L;\mathbf{S}) = \int_{-\theta \log(\tau_{in})}^{\theta \log(\tau_{ni})} \epsilon_{ni} f_{\max}(\epsilon_{ni}; L, \mathbf{S}) d\epsilon_{ni} \; < \; \theta \log(\tau_{ni})$$

$$\epsilon_{ni} = \theta(\log p_n - \log p_i), \qquad f_{\max}(\epsilon_{ni}; L) = \text{pdf of } \max\{\epsilon_{ni}\},$$

$$\Omega_{ni} = \int_{-\theta \log(\tau_{in})}^{\theta \log(\tau_{ni})} \epsilon_{ni} f(\epsilon_{ni}) d\epsilon_{ni}, \qquad \mathbf{S} = \{\log(T_1 w_1^{-\theta}), \ldots, \log(T_n w_n^{-\theta})\}.$$

Why? Because Max Price Δ < True Trade Cost

If the value of the max price Δ equals the trade cost in expectation, no problem.

$$\int_{-\theta \log(\tau_{in})}^{\theta \log(\tau_{ni})} \epsilon_{ni} f_{\max}(\epsilon_{ni}; L, \mathbf{S}) d\epsilon_{ni} \; = \; \theta \log(\tau_{ni}) \quad \Rightarrow \quad E(\hat{\beta}) = \theta$$

This can not be the case.

- With positive probability the max price Δ $<$ the true trade cost.
- With zero probability it can not be larger than the true trade cost.

Thus $$\int_{-\theta \log(\tau_{in})}^{\theta \log(\tau_{ni})} \epsilon_{ni} f_{\max}(\epsilon_{ni}; L, \mathbf{S}) d\epsilon_{ni} \; < \; \theta \log(\tau_{ni}) \quad \Rightarrow \quad E(\hat{\beta}) > \theta$$

How Large is the Bias . . .

Simple monte carlo exercise:

- Simulate the model with a known θ.
- Apply EK (2002) estimation approach.

Monte Carlo Results, True $\theta = 8.28$

Approach	Mean Estimate of θ (S.D.)	Median Estimate of θ
EK (2002) Estimator	12.5 (0.60)	12.5
Least Squares	12.1 (0.60)	12.1

Note: In each simulation there are 19 countries and 100,000 goods. Only 50 realized prices are randomly sampled and used to estimate θ. 100 simulations performed.

Proposition 2: As $L \to \infty$, the Bias is Eliminated

As the sample size L approaches ∞,

$$\text{plim}_{L\to\infty} \; -\theta \frac{\sum_n \sum_i \log\left(\frac{X_{ni}/X_n}{X_{ii}/X_i}\right)}{\sum_n \sum_i (\Psi_{ni}(L; \mathbf{S}) - \Omega_{ni})} = \theta$$

In words:

- As the sample size increases, the probability that the max price $\Delta < \tau$ becomes vanishingly small.
- Problem — the sample size needs to be very large.

How Much Data is Really Needed . . .

Another monte carlo exercise:

- Simulate the model with a known θ.
- Vary the sample size and apply EK (2002) estimation approach.

Monte Carlo Results, True $\theta = 8.28$

Sample Size of Prices	Mean Estimate of θ (S.D.)	Median Estimate of θ
50	12.14 (0.60)	12.15
500	9.41 (0.22)	9.40
5,000	8.47 (0.08)	8.46
50,000	8.29 (0.06)	8.29

Note: S.E.M. is the standard error of the mean. In each simulation there are 19 countries and 100,000 goods. 100 simulations performed.

What Does This All Mean? Need A New Estimation Strategy

Proposition 1 $\Rightarrow$

- EK (2002) estimate is, at best, an upper bound.
  - Not a tight one though ...
- Welfare gains from trade are underestimated.

Proposition 2 $\Rightarrow$

- Finding and adding more data is not feasible.

This motivates an alternative estimation strategy.

New Estimation Approach — Overview

Use simulated method of moments . . .

- Moment is the estimate from EK (2002) approach.
  - Proposition 1 $\Rightarrow$ this is a meaningful moment.
- Our estimator minimizes the distance between the moment on artificial and real data.

Next couple of slides

- Formalize this idea.
- Monte carlo evidence that our approach works.
- Results using new ICP price data for 123 countries.

Simulation Approach Overview

1. Fix θ.
2. Estimate marginal cost parameters $(w_i^{-\theta} T_i)$ and $\theta \log(\tau_{ni})$ — up to an unknown scalar θ — from only trade data, via gravity.
3. Discretize the continuum. Simulate trade flows and micro-level prices.
4. Define subset of goods common to all countries and collect sample of prices.
    - 50 as in EK (2002) data, 62 as in 2005 ICP data.
5. Estimate $\beta(\theta)$ using artificial data and compare β from real data.
6. Update θ until $\beta(\theta)$ is "close" to β.

Moments

Data moment is:

$$\beta = -\frac{\sum_n \sum_i \log\left(\frac{X_{ni}/X_n}{X_{ii}/X_i}\right)}{\sum_n \sum_i \left(\log \hat{\tau}_{ni} + \log \hat{P}_i - \log \hat{P}_n\right)}$$

Model moment $\beta(\theta, u_s)$ is the analog using artificial data.

- u_s is vector of random variables specific to simulation s.

Zero Function, Moment Condition and an Estimator

A zero function

$$y(\theta) = \left[\beta - \frac{1}{S} \sum_{s=1}^{S} \beta(\theta, u_s) \right].$$

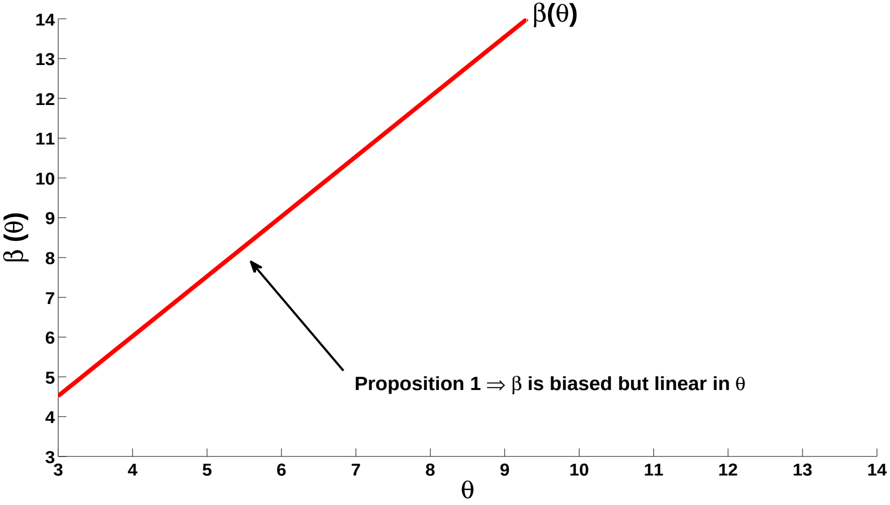
Our estimation is based on the moment condition

$$E\left[y(\theta_o)\right] = 0, \qquad \text{where} \;\; \theta_o = \text{true} \;\; \text{value}.$$

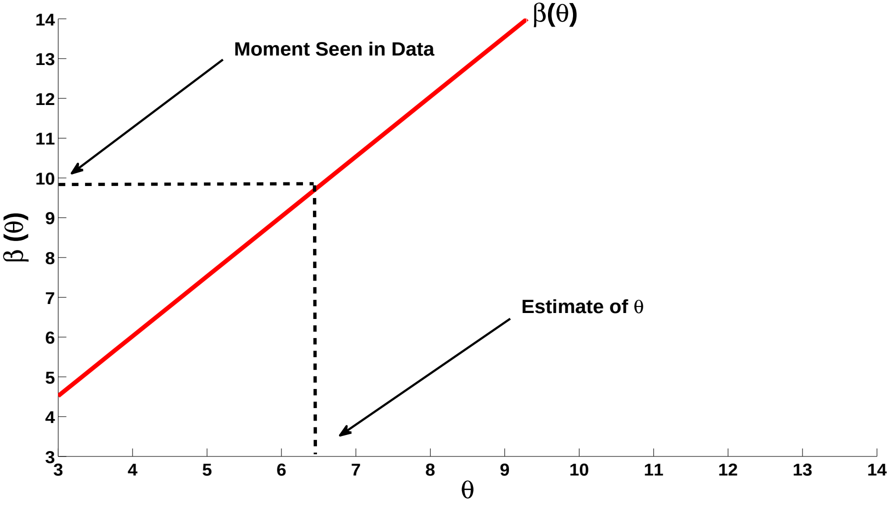
Thus our estimator is . . .

$$\hat{\theta} = \arg\min_{\theta} \left[y(\theta)' y(\theta) \right].$$

Intuition Behind Our Approach...



Intuition Behind Our Approach. . .



Does Our Approach Work? Yes.

Estimation Results With Artificial Data

Estimation Approach	Mean Estimate of θ	Standard Deviation
	True θ = 8.28	
SMM	**8.19**	0.41
EK (2002) Estimator, β	12.37	0.61

Note: In each simulation there are 19 countries and 100,000 goods and 100 simulations performed.

Overview of New 2005 ICP Data

Data:

- Prices in 123 countries for 62 tradeable products during 2003-2005.
  - Price data on goods with identical characteristics across retail locations in the participating countries.
  - Analogous to data used in EK (2002), but more countries & goods
- Trade shares from data on bilateral trade and production of manufactures among 123 countries in 2004.

Estimation Results With 2005 ICP Data

Estimation Approach	Estimate of θ	Standard Error
SMM	**4.22**	0.08
EK (2002) Estimator, β	7.75	0.03

Note: In each simulation there are 123 countries and 100,000 goods. Only 62 realized prices are randomly sampled.

Overview of Estimates: Consistent with Alternatives in the Literature

Our estimates range from 3.9 to 4.5, not 7 to 9 as EK (02) approach suggests.

Our estimates are consistent with approaches not using max over price data . . .

- EK (2002) using wage data: 3.6
- BEJK (2003)/EKK (2008) using U.S./French firm level data: 3.6/4.8
- Donaldson (2009) price of salt: 3.8 to 5.2
- Burstein and Vogel (2009) skill intensity in U.S. trade: 4
- Simonovska (2009) average mark-up in OECD: 3.8

Our (implied) estimates of ρ range from 3.4 to 5.2 and are consistent with:

- Romalis (2007): 4-13
- Hummels (2001): 3-8
- Broda and Weinstein (2006): median of 3.1

Why This Matters. . . Large Welfare Implications

Why care about θ?

Welfare cost of autarky:

$$\frac{1}{\theta} \log\left(\frac{X_{nn}}{X_n}\right).$$

- $\frac{X_{nn}}{X_n}$ = domestic expenditure share.
- $\frac{X_{nn}}{X_n} = 1$ in autarky.

New θ of 4 rather than 8 **doubles** the welfare cost of autarky.

Why This Matters. . . Micro-level Heterogeneity Matters

Arkolakis, Costinot, and Rodriguez-Clare (2009):

- New trade models with micro-level heterogeneity and older models without heterogeneity generate previous formula,
- $\Rightarrow$ new trade models yield no additional welfare gains from trade above older models.

But. . .

- Only if these models have the same θ.
- And micro-level heterogeneity affects the inference about θ — our paper demonstrates this.

Moving forward. . .

- Use our approach within the Melitz framework.

Conclusion

What we did . . .

Proved that EK (2002) estimate is biased upward. Monte carlo evidence supported this.

- Small sample of prices $\Rightarrow$ poor approximation of trade frictions.

New method to estimate θ under same data requirements as EK (2002) and applied it to a new data set for 123 countries that comprise 98% of world GDP.

New θ is 4, rather than 8.

- **Doubles** the welfare cost of autarky.

Robustness

Estimates of θ are robust to:

- Number of goods — as long as it is large (50,000+)
- Measurement error — as long as it is not too large ($\leq$ 20% of price)
- Aggregation — used more disaggregate data from EIU
  - Approach yields lower estimates ≈ 2.6
- Country-specific taxes & distribution costs
  - Model with ad-valorem tax yields identical estimating equation
- Good- and country-specific mark-ups
  - Estimates from high- and low-end stores using EIU data are similiar